PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

VOL. XLVIII—No. 5

AMERICAN SOCIETY OF CIVIL ENGINEERS FOUNDED 1852

May, 1922

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NEW YORK 1922

American Society of Civil Engineers

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RICHARD L. HUMPHREY		M. G. BARNES
J. J. YATES		A. H. MARKWART

Special Committees

To Codify Present Practice on the Bearing Value of Soils for Foundations, etc.: Robert A. Cummings, E. G. Haines, Allen Hazen, James C. Meem, Walter J. Douglas.

To Report on Stresses in Railroad Track: A. N. Talbot, A. S. Baldwin, G. H. Bremner, John Brunner, W. J. Burton, Charles S. Churchill. W. C. Cushing, W. M. Dawley, H. E. Hale, Robert W. Hunt, J. B. Jenkins, George W. Kittredge, Paul M. LaBach, C. G. E. Larsson, G. J. Ray, Albert F. Reichmann, H. R. Safford, Earl Stimson, F. E. Turneaure, J. E. Willoughby.

On Highway Engineering: H. Eltinge Breed, George W. Tillson, A. B. Fletcher, John M. Goodell.

On Bridge Design and Construction: Henry B. Seaman, Howard C. Baird, Victor H. Cochrane, Otis E. Hovey, C. W. Hudson, M. S. Ketchum, B. R. Leffler, F. E. Turneaure.

On Contract Standard Clauses: H. Eltinge Breed, J. H. Brillhart, J. S. Langthorn, Edward H. Lee, Hunter McDonald, George H. Pegram, Henry H. Quimby.

On Industrial Education: Herman Schneider, E. J. Mehren, Leonard S. Smith.

On Research: A. N. Talbot, F. E. Schmitt, Robert A. Cummings, W. C. Cushing, A. T. Goldbeck, D. C. Henny, R. E. Horton, Anson Marston, F. E. Turneaure.

On Electrification of Steam Railways: Charles F. Loweth, B. J. Arnold, George Gibbs, George W. Kittredge, E. J. Pearson, Samuel Rea, Robert Ridgway.

The Reading Room of the Society is open from 9 A. M. to 6 P. M., and from 7 P. M. to 10 P. M., every day, except Sundays, New Year's Day, Washington's Birthday, Memorial Day, Fourth of July, Labor Day, Thanksgiving Day, and Christmas Day; during July and August, it is closed at 6 P. M.

Headquarters of the Society—33 West Thirty-ninth Street, New York.

Telephone Number........................7100 Longacre.
Cable Address........................"Ceas, New York."

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PROCEEDINGS

SOCIETY AFFAIRS

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MINUTES OF MEETINGS

OF THE SOCIETY

May 3d, 1922.—The meeting was called to order at 8:10 P. M.; President John R. Freeman in the chair; Elbert M. Chandler, Acting Secretary; and present, also, 62 members and guests.

The minutes of the meeting of April 5th, 1922, were approved as printed in *Proceedings* for April, 1922.

The following deaths were announced:

Wilbur Fisk Foster, of Nashville, Tenn., elected Member, May 7th, 1873; died March 27th, 1922.

Sylvan Earle Ganser, of St. Paul, Minn., elected Associate Member, January 2d, 1912; Member, January 18th, 1921; died April 14th, 1922.

Lawrence Bates Jenckes, of Worcester, Mass., elected Junior, March 31st, 1891; Associate Member, October 7th, 1896; Member, September 6th, 1910; died March 29th, 1922.

Charles Miller Morse, of Mount Dora, Fla., elected Member, January 2d, 1895; date of death unknown.

Horace Edward Stevens, of St. Paul, Minn., elected Junior, November 1st, 1875; Member, April 4th, 1888; died February 15th, 1922.

Frank Ephraim Chesley, of Goldsboro, N. C., elected Associate Member, December 31st, 1913; died January 9th, 1922.

George Robert Davis, of Sacramento, Calif., elected Associate Member, April 3d, 1907; died March 31st, 1922.

Louis William Klingner, of Baghdad, Mesopotamia, elected Junior, October 31st, 1911; Associate Member, June 24th, 1914; died April 2d, 1922.

Clarence Ivan Lantz, of Morgantown, W. Va., elected Associate Member, October 1st, 1913; died September 4th, 1921.

Emeret Claude Neudecker, of Storm Lake, Iowa, elected Associate Member, April 19th, 1920; died June 8th, 1921.

President Freeman reported on the Spring Meeting of the Society held at Dayton, Ohio, on April 5th to 7th, 1922, inclusive. In this connection, a series of moving picture films and lantern slides of the works visited, etc., were shown for the benefit of the local members.

A paper entitled "The American Mixed-Flow Turbine and Its Setting", by Arthur T. Safford, M. Am. Soc. C. E., and Edward Pierce Hamilton, Esq., was presented by Mr. Safford. Written discussions by Messrs. W. M. White and Forrest Nagler were presented by the Acting Secretary, and the subject was discussed orally by Messrs. E. P. Hamilton, G. A. Orrok, and President Freeman.

Adjourned.

DAYTON, OHIO, MEETING

April 5th, 1922.—The Spring Meeting of the Society was called to order at 10 A. M., at the Engineers' Club, Dayton, Ohio; President Charles H. Paul of the Dayton Section in the chair; Elbert M. Chandler, Acting Secretary; and present, also, about 350 members and guests.

Chairman Paul introduced Col. E. A. Deeds, Chairman of the Board of Directors of the Miami Conservancy District and President of the Engineers' Club of Dayton, who presented an address of welcome.*

President John R. Freeman of the Society was then introduced by the Chairman and replied† to the welcome extended by Col. Deeds.

President Freeman took the chair.

A symposium on "Flood Problems"‡ was opened by J. G. Sullivan, M. Am. Soc. C. E., who addressed the meeting on "Flood Conditions in Canada." Mr. Sullivan was followed by Gerard H. Matthes, M. Am. Soc. C. E., whose subject was "Floods on Small Streams Caused by Rainfall of the Cloudburst Type". A paper on "Standing Waves in Rivers" was presented by Nathan C. Grover, M. Am. Soc. C. E.

Adjourned at 12 M., to meet again at 2:15 P. M.

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* See p. 392.

† See p. 393.

‡ See Papers and Discussions, p. 1091.

April 5th, 1922.—The meeting was called to order at 2:15 P. M.; President John R. Freeman in the chair; and present, also, about 350 members and guests.

In continuation of the symposium on "Flood Problems", President Freeman presented a paper on "Flood Problems in China", illustrating his remarks with lantern slides. President Freeman was followed by J. A. Ockerson, Past-President, Am. Soc. C. E., who discussed the subject, "Flood Control of the Mississippi River". A paper by Roy N. Towl, M. Am. Soc. C. E., on "Missouri River Bank Protection at Omaha, Nebraska", which was illustrated by moving pictures, was presented by the author.

After a recess and some announcements by Mr. Paul, a paper on "Flood Problems in the Arid Regions", was presented by A. P. Davis, Past-President. Am. Soc. C. E. Mr. Davis was followed by C. E. Grunsky, M. Am. Soc. C. E., who discussed "Some Factors Affecting the Problem of Flood Control", illustrating his remarks with lantern slides.

The addresses were followed by oral discussion of the general subject by Messrs. Morris Knowles, Harrison P. Eddy, C. E. Grunsky, and J. G. Sullivan.

Adjourned at 6:15 P. M., to meet again at 8:15 P. M.

April 5th, 1922.—The meeting was called to order at 8:15 P. M.; President John R. Freeman in the chair; and present, also, about 320 members and guests.

President Freeman introduced Arthur E. Morgan, M. Am. Soc. C. E., who addressed the meeting on "Factors in Engineering Accomplishment, the Miami Conservancy Project".* Mr. Morgan was followed by Charles H. Paul, M. Am. Soc. C. E., whose subject was "Flood Control in the Miami Valley, Ohio."†

The addresses were followed by oral discussion of the general subject by Messrs. J. Albert Holmes, who illustrated his remarks with lantern slides, D. W. Mead, Arthur O. Ridgway, and A. P. Davis.

Adjourned.

EXCURSIONS AND ENTERTAINMENTS, DAYTON, OHIO, MEETING

Monday, April 3d, 1922.—6:30 P. M.—The members of the Board of Direction of the Society and of the Dayton Section had dinner at the Engineers' Club of Dayton, with 38 members of the Dayton Section attending. The guests of honor included the former Governor of Ohio, the Hon. James M. Cox, Col. E. A. Deeds, Mr. Orville Wright, Maj. T. H. Bane, Commanding Officer of McCook Aviation Experimental Field, and Mr. Edward Wuichet, President of the Dayton Chamber of Commerce. Short addresses were made by Messrs. Freeman, Cox, Deeds, Bane, and Wuichet.

Tuesday, April 4th, 1922.—6:30 P. M.—The Board of Governors of the Engineers' Club of Dayton entertained the members of the Board of Direction at dinner at the Engineers' Club, in honor of the speaker at the regular Tuesday evening meeting of the Club, Mr. Paul Lincoln, who later gave a

* See p. 397.

† See Papers and Discussions, p. 1206.

talk in the Auditorium on "Some Important Factors in the Sale of Electric Service". President John R. Freeman also addressed the meeting, recounting some of his experiences while visiting with engineers in Europe.

Wednesday, April 5th, 1922.—The Chamber of Commerce of Dayton held a luncheon in the ballroom of the Miami Hotel, in honor of the members of the Society, at which about 500 members and guests were present, who listened to interesting talks by J. G. Sullivan, President, Engineering Institute of Canada, and President John R. Freeman. Just preceding the luncheon, the aviators at McCook Field staged a thrilling aerial circus over the river channel immediately in front of the Club.

Thursday, April 6th, 1922.—9:30 A. M.—About 250 members and guests spent an hour examining the Englewood Dam, arriving at 10:00 A. M. Enough water was passing through the conduits to show in a small way the action of the hydraulic pump at the outlet works.

On completing their inspection, the visitors were then taken to the City Club of the National Cash Register Company, where Dr. Charles Garland, the Welfare Director of the Company, gave an illustrated talk on the history of this great industry and its notable welfare work. He also gave a graphic account of the great Dayton Flood of 1913, and described the work of the Company for the flood sufferers. At 12:45 P. M., the party was conveyed to the plant of the National Cash Register Company, where a luncheon was served in the Officers' Club, on the 10th floor of the Administration Building. After luncheon, the party adjourned to the roof of the building, where a general view of the local flood-protection work along the Dayton Channel was obtained, and Mr. C. A. Bock, Division Engineer in charge of the Dayton Channel Improvements, gave a brief description of the character and volume of the work. After a trip through the plant, the visitors were taken to the Huffman Dam, on the Mad River, where an hour was spent in looking over this project. The outlet works at this dam are particularly interesting, as the conduits and spillway are combined. The conduits of this dam are much larger than those at the Englewood Dam where a much larger storage capacity enabled a more complete control of the flood flow. The party returned to Dayton at 4:45 P. M.

At 6:30 P. M., a dinner and smoker were held in the ballroom of the Miami Hotel, at which about 230 members and guests were present. Mr. Charles H. Paul, President of the Dayton Section, acted as Toastmaster, and introduced Mr. H. S. R. McCurdy, Chairman of the Local Committee of Arrangements, who introduced Col. E. A. Deeds, Chairman of the Board of Directors of the Miami Conservancy District. Col. Deeds gave an interesting talk on "Some Human Phases of the Miami Conservancy Projects." Edward E. Wall, Vice-President, Am. Soc. C. E., followed with a brief talk. Through the courtesy of the National Cash Register Company, a series of moving pictures of the various activities during the Spring Meeting were then shown.

Friday, April 7th, 1922.—9:30 A. M.—About 200 members and guests were taken by automobile for an inspection of the main features of the improved river channel through Dayton, which work is practically completed. The party was then taken to McCook Field, the Experimental Station of the U. S.

Air Service, where they were divided into small groups, to each of which was assigned an Officer as escort. An address of welcome was given by Maj. T. H. Bane, Commanding Officer of McCook Field. He was followed by 5-min. talks by the men in charge of experiments with the lighter alloys and aerial photography and mapping. The parties were then conducted through the woodworking shops, where the construction of wings and propellers was seen; the motor-testing laboratory, where various types of motors were under test; the wind tunnel building, where tests of the effect of wind pressure on models of buildings and a wireless tower were being conducted in the largest wind tunnel in the United States; past the propeller testing stand, capable of applying 1 000 h. p. to the test of propellers; and through the hangar where the wings of planes are tested with sand-bag loads applied to simulate actual stresses encountered in the air. The party then went to the Flying Field, where there was drawn up in review, one of every type of plane at the Field, from tiny pursuit planes weighing less than 300 lb. to heavy triplane bombers weighing 14 000 lb. Much interest was shown in a housed-in passenger plane, capable of carrying 2 pilots and 12 passengers. A wonderful flying exhibit was then given in which most of these planes were used. This trip was one of the most interesting features of the meeting.

The visitors were then taken by automobile to the Union Station in Dayton, where a special train was boarded for the trip to the plant of the American Rolling Mill Company, at Middleton, Ohio. After arrival at the plant at 1:30 P. M., luncheon was served in the Administration Building, and after a brief address of welcome by Mr. Hook, the General Manager, and a reply by C. E. Grunsky, Vice-President, Am. Soc. C. E., the party was conducted through the plant in charge of guides, who explained the various processes in the manufacture of Armco iron. The party left at 5:15 P. M., by special train, arriving at Dayton at 6:30 P. M.

OF THE BOARD OF DIRECTION

(Abstract)

April 3d, 1922.—The Board met at 10 A. M., at the Engineers' Club, Dayton, Ohio; President John R. Freeman in the chair; Elbert M. Chandler, Acting Secretary; and present, also, Messrs. Anderson, Brown (came in at 10:25 A. M.), Chester, Curtis, Darrow, Davis, Dyer, Greene, Grunsky, Henny, Hogan, Holland, Huber, Hudson, Humphrey, Hunt, Marston, O'Connor, Pegram, Ridgway, Talbot, Wall, Webster, Winsor, and Yates.

On motion of Director Humphrey, seconded by Director Henny, and carried, the minutes of the meetings of the Board held January 16th and 17th, and January 18th and 20th, 1922, were approved.

Progress Report of Publication Committee

The Acting Secretary read the following progress report from the Publication Committee:

"In accordance with the instructions of the Board of Direction at its meeting of October 10th, 1921, the Publication Committee has made a partial sur-

vey of the situation in regard to advertising and reports progress to date as follows:

"Inquiry from the other three Founder Societies shows net returns from advertising of the following sums:

American Institute of Mining and Metallurgical Engineers	$7 800.00
American Society of Mechanical Engineers	71 000.00
American Institute of Electrical Engineers	28 557.98

"Inquiry from the American Institute of Mining and Metallurgical Engineers showed that the net proceeds from advertising before the war were approximately 50% of the gross, but that for 1922, according to present indications, the net profit would be only 30% of the gross receipts. Practically this same proportion is borne out by the Mechanical Engineers.

"Mr. Walter B. Snow, an advertising man of Boston, Mass., who has specialized in technical work, was asked for information and suggestions on this plan, and replied in substance as follows:

" 'The essentials which an independent publisher would consider necessary to success from the standpoint of business efficiency become obstacles in the eyes of the members in so far as they tend to disturb their conservatism and offend their dignity. The hazard is certainly great where diplomacy must play so large a part in working out a plan that is likely to give offense to so many. It appears that unless it is put over with a firm hand and traditions are somewhat ruthlessly broken down its progress will be slow and its success will be limited.'

" 'Under the conditions, I do not feel like making either a recommendation or a prophecy.'

"About two years ago, E. J. Rosencrans, M. Am. Soc. C. E., appeared before the Publication Committee and discussed the possibility of publishing the *Proceedings* of the Society free of expense to it, in exchange for the use of the *Proceedings* as an advertising medium. This was not entered into at the time for the reason that printing costs were increasing rapidly and were very uncertain. Mr. Rosencrans has been communicated with and asked if he cared to submit a proposal at the present time. He declined to do so.

"Mr. Edward G. Nellis, an expert in technical advertising, has been consulted at length, and on March 21st, 1922, submitted to the Acting Secretary an expression of his views on the subject. In brief, he urges the adoption of the plan followed by the Mechanical Engineers, of a journal of the standard journal size, 9 by 12-in. page in lieu of *Proceedings,* 6 by 9 in. However, he does express the opinion that a fair volume of advertising business could be obtained in *Proceedings* as at present conducted, at a rate which would be profitable to the Society. Furthermore, he has offered to furnish any additional details, or to make for us, a special study and analysis of the whole situation if it is desired that he undertake it.

"Mr. Humphrey, of the Committee, has offered to see what he can do in the way obtaining a few pages of advertisements for the 6 by 9-in. size."

Discussion on this report was participated in by President Freeman and Messrs. Brown, Chester, Curtis, Davis, Grunsky, Henny, Hogan, Hudson, Humphrey, Hunt, Marston, Ridgway, Talbot, Webster, and Winsor, arguments both for and against advertising being presented.

On motion of Past-President Curtis, seconded by Director Humphrey, and carried, the report was received.

The President inquired whether the Board cared to give any instructions to the Publication Committee, and there was some further discussion by Messrs. Anderson, Curtis, Hogan, and Humphrey.

The following motion was then offered by Vice-President Hunt, seconded by Director Humphrey, and carried unanimously:

"*Moved,* That the Publication Committee be requested to present to the Board at its next meeting a definite plan for soliciting and printing advertisements in *Proceedings,* setting forth the salient features in such a way that each may be separately acted on."

Report of Committee on Special Committees

Chairman Davis, of the Committee on Special Committees, reported verbally for his Committee as follows:

(1) In regard to the desirability of a Committee of the Society on Military Affairs (suggested by R. D. Coombs, M. Am. Soc. C. E., in a letter dated March 9th, 1921):

The Committee recommended no action at the present time.

(2) Suggested Joint Committee to Study the Housing Problem (this matter was referred by the Board at its January meeting to the Committee on Special Committees):

The Committee recommended that the Acting Secretary be instructed to correspond with the American Society of Mechanical Engineers and the American Institute of Architects with a view of some sort of co-operative action if it seems appropriate thereafter.

(3) Acceptance by the Society of responsibility for sponsorship and the organization of a representative Sectional Committee for the Unification of Existing and Proposed Specifications for Steel Railway Bridges (this matter was referred by the Board at its January meeting to the Committee on Special Committees):

Chairman Davis reported as follows:

"That this Society has a Committee on Specifications for Bridges, including not only railway bridges but highway bridges, and not only steel bridges but any other bridges that might be proposed. That Committee has not yet reported, except progress. For reasons, including a better representation of highway bridges as distinguished from railway bridges, the Committee on Special Committees thinks it is probable that it would be advisable to expand by increasing the membership of that Specifications Committee rather than to accept this sponsorship that has been proposed, and, therefore, recommends that the President of this Society be authorized to appoint not more than five additional members of the Committee on Bridge Specifications on the recommendation of the Committee on Special Committees.

"The thought is to secure the co-operation and assistance of the Committee of the American Association of State Highway Officials which has this matter under consideration and with which it is very desirable to secure uniform results; also to secure some co-operation with the Canadian Society which is now considering this subject so as to have an uniform specification as a final result."

(4) Question of adopting resolution *re* Pollution of Water by Industries (suggested by Charles Haydock, Assoc. M. Am. Soc. C. E., and referred by the Board at its January meeting to the Committee on Special Committees):

The Committee recommended the adoption of the following resolution:

"*Resolved:* That the United States Government be requested to undertake, through the Department of Commerce, a complete investigation of the cause, extent and effect of pollution of waters by industries, that methods of mitigating such evils be investigated, and that existing legislation be reviewed in order to determine what if any legislation is required to cope with the situation."

On motion of Vice-President Hunt, seconded by Director Humphrey, and carried, the recommendation of the Committee on Special Committees regarding the first subject in the report, that is, the desirability of a Committee of the Society on Military Affairs, was adopted.

Director Humphrey offered an amendment concerning the second subject that the words, "and such other organizations that may be directly interested in the housing question", be added, to which Past-President Davis agreed, and on motion of Vice-President Hunt, duly seconded and carried, the recommendation of the Committee on Special Committees as amended, regarding the suggested Joint Committee to Study the Housing Problem, was adopted.

After discussion concerning the third subject of the report, participated in by Messrs. Davis, Hudson, Humphrey, Marston, Talbot, Webster, and Yates, on motion of Director Marston, seconded by Past-President Davis, the following motions were carried unanimously:

"Reply is to be made to the American Engineering Standards Committee that the American Society of Civil Engineers will accept sponsorship at the proper time, but it is thought such time has not yet arrived."

"That the President be authorized to appoint not more than five additional members on the Special Committee on Bridge Design and Construction on the recommendation of the Committee on Special Committees."

On motion of Past-President Webster, seconded by Director Humphrey and carried, the recommendation of the Committee on Special Committees regarding the question of adopting a resolution *re* Pollution of Water by Industries was adopted.

Chairman Humphrey, of the Committee on Licensing Engineers, made a verbal progress report, and on motion of Director Henny, seconded by Vice-President Grunsky, and carried, the Committee was continued.

Code of Ethics and Committee on Professional Conduct

Chairman Winsor, of the Committee Considering a Proposed Universal Code of Ethics and the Appointment of a Committee on Professional Conduct, reported verbally for his Committee, outlining the history of the whole matter. Extended discussion was participated in by Messrs. Chester, Hudson, Humphrey, Hunt, Talbot, Webster, and Winsor.

The following revised motion offered by Director Winsor, seconded by Director Humphrey, was carried:

"Be it Resolved: That the Code be not approved."

On motion of Director Winsor, seconded by Director Humphrey and carried unanimously, the President was authorized to appoint a Standing Committee of Three on Professional Conduct, this Committee to be composed of members of the Board of Direction.

On motion of Director Humphrey, duly seconded and carried, Director Winsor's Committee on a Proposed Universal Code of Ethics was discharged with the thanks of the Board.

Chairman Brown, of the Committee to Consider the Whole Question of the Status of the Civil Engineer in Government Work and His Compensation, reported progress.

Chairman Humphrey, of the Committee to Report on Re-arrangement of the Fifteenth Floor, reported progress.

Chairman Wall, of the Committee to Prepare Policy for Collection of Funds for Bust of Captain Eads, reported progress ($1 337.26 is the amount of subscriptions received to date).

STUDENT CHAPTERS

Chairman Marston, of the Committee on Student Chapters, presented the following report:

"DAYTON, OHIO, APRIL 3, 1922.

"BOARD OF DIRECTION,

"American Society of Civil Engineers.

"GENTLEMEN.—The Committee on Student Chapters would report as follows on the matters which have been referred to us:

"1.—Criterion for 'High Standing' of Engineering Schools:

"Article V, By-Laws of the American Society of Civil Engineers, provides that one of the qualifications required of a proposed Student Chapter shall be:

" '(*a*).—An organization of students in an engineering school of high standing.'

"The question is what shall be the criterion for 'high standing'. We recommend that the criterion shall be:

"(*a*) Entrance requirements substantially equal to four years of work in an accredited high school. (15 units).

"(*b*) The maintenance of a well organized Department of Civil Engineering in charge of a Professor of Civil Engineering of high standing.

"(*c*) A Civil Engineering Faculty of high standing and satisfactory in numbers as compared with student attendance.

"(*d*) A Civil Engineering Department equipment adequate and satisfactory as compared with student attendance.

"(*e*) At least four years of high grade undergraduate college work, or its equivalent, as prerequisite to a degree.

"(*f*) A regular Civil Engineering Student attendance of at least 12 Juniors and Seniors, in order to insure the permanent maintenance of a strong Student Chapter.

"2.—Admission of Student Chapters:

"(*a*) We recommend the immediate admission of the Student Chapters applied for at:

"Clemson Agricultural and Mechanical College of South Carolina; The Georgia School of Technology; Norwich University; The University of Virginia; Worcester Polytechnic Institute. All, however, on condition the applications shall be found by the Acting Secretary to be in proper form and to comply with the requirements of Article V, By-Laws.

"Respectfully submitted,

"C. W. HUDSON,
"A. N. TALBOT,
"ANSON MARSTON."

On motion of Director Brown, duly seconded and carried, this report was adopted and the Committee continued.

Chairman Brown, of the Public Relations Committee, reported progress. He reported that the majority of his Committee was in favor of joining the Federation.

Replies from Local Sections *re* Joining the Federated American Engineering Societies

Verbal reports were made by the Directors, as to action taken by the various Local Sections in their Districts on the question of the Society joining the Federated American Engineering Societies, as follows:

District:	Report from Director:	Local Section:	Sentiment:
No. 1	Hogan	New York	Opposed
No. 2	Winsor	Northeastern	Not heard from
		Connecticut	Opposed
		Providence	Opposed
No. 3	O'Connor	Buffalo	Opposed
No. 4	Humphrey	Philadelphia	Not heard from
		Baltimore	" " "
No. 5		Dist. of Columbia	In favor
		Atlanta	Not heard from
No. 6	Chester	Pittsburgh	In favor
		Central Ohio	In favor
		Cincinnati	Opposed
		Cleveland	In favor*
		Toledo	Not heard from
		Dayton	" " "
No. 7	Marston	Iowa	In favor
		Northwestern	Not heard from
		Detroit	In favor
		Duluth	In favor†
No. 8	Dyer	Nashville	In favor
		Illinois	Think no commitment should be made without taking letter-ballot
No. 9	Brown	St. Louis	In favor
		Kansas City, Mo.	Opposed
		Louisiana	In favor
No. 10	Darrow	Nebraska	Not heard from
		Colorado	" " "
		Kansas	" " "
		Utah	" " "
		Oklahoma	" " "
No. 11	Anderson	Los Angeles	In favor
		San Diego	" "
		Texas	" "
No. 12	Henny	Portland, Ore.	Opposed
		Seattle	Not heard from
		Spokane	" " " ‡
No. 13	Huber	San Francisco	Opposed.

Director Humphrey moved and Director Dyer seconded the motion, that the matter go over until the next meeting of the Board.

Director Brown suggested that the Acting Secretary call the attention of the Secretaries of the Local Sections to the rule requiring that Local Sections

* As soon as finances permit.

† Resolution suggests letter-ballot.

‡ The Acting Secretary reminded the Board that the Spokane Section had previously forwarded telegram in favor.

give the number of Corporate Members present when a vote is taken, and the name of the presiding officer.

Director Hogan offered as an amendment, that the matter be laid on the table. This was seconded by Director Hudson and lost by vote resulting in 11 ayes and 14 noes.

After further discussion participated in by Messrs. Anderson, Curtis, Grunsky, Henny, Hogan, Holland, Hudson, Humphrey, Marston, Ridgway, and Talbot, Director Humphrey's motion was carried with the understanding that reports would again be asked for, from the Sections not yet heard from.

Director Humphrey made a verbal progress report as the representative on the Joint Committee on New Pay Employment Bureau.

Visits of Acting Secretary to Local Sections

The Acting Secretary reported that during the week of February 20th, 1922, in accordance with authority of the Executive Committee, he had visited the following Local Sections: Dayton, Cleveland, Cincinnati, Central Ohio, Toledo, and Pittsburgh.

Proposed Amendments to By-Laws Regarding Student Chapters

It was reported that written notice had been given at the Board meeting of January 16th, 1922, of the Proposed Amendment to the By-Laws concerning the rule regarding the name of Student Chapters, and a copy had been mailed to each Director so that the matter now came up for final action.

On motion of Past-President Talbot, seconded by Director Marston and carried unanimously, the footnote applying to Section 1 of Article V of the By-laws was ordered amended by adding the following:

"Chapters which desire to retain local names well established by tradition may do so by inserting such local names followed immediately by the name of the institution in parentheses; for example, 'William Cain (University of North Carolina)."

making the footnote read:

"Insert the name of the educational institution at which the particular Student Chapter is situated, for example, 'Yale University'. Chapters which desire to retain local names well established by tradition may do so by inserting such local names followed immediately by the name of the institution in parentheses; for example, 'William Cain (University of North Carolina)'."

It was reported that written notice had been given at the Board meeting of January 16th, 1922, of the proposed amendment to the By-laws regarding changing the time of payment of dues of Student Chapters, and a copy had been mailed each Director, so that the matter now came up for final action.

On motion of Director Marston, seconded by Past-President Talbot, and carried, Section 6 of Article V of the By-laws was amended by striking out the last paragraph and inserting the following in lieu thereof:

"The annual dues shall apply to the year beginning July 1, and shall be due October 1 of such year. Student Chapters admitted on or after January 1 of each year shall pay only $5.00 for the remainder of the current year to July 1."

On motion of Director Marston, seconded by Director Henny and carried, it was decided that each Chapter which has paid its dues for 1922, shall be required to pay only $5 on October 1st, 1922.

Professional Divisions

The Acting Secretary reported that the Publication Committee has recommended that a By-law be prepared to make provision for the orderly formation of Professional Divisions within the Society, and the following was suggested:

"Article VII—Professional Divisions

"(1) A Professional Division of the American Society of Civil Engineers may, with the approval of the Board of Direction, be organized for the consideration of any engineering, scientific, or professional subject, provided that a number, satisfactory to the Board of Direction, of members of the Society unite in making written request for such an organization. Such a Division shall be designated as .... Division of the American Society of Civil Engineers, the blank being filled by the subject specialized.

"(2) Members of the Society of any grade may be members of the Division upon enrollment without additional dues.

"(3) For the convenient conduct of its professional affairs, the President shall appoint annually, an Executive Committee of five members to have charge of the affairs of the Division under the guidance of the Board. Other committees of the Division shall be appointed by its Executive Committee.

"(4) Expenditures for the purpose of the Division chargeable to the Society must be authorized by the Board of Direction before they are incurred, and must be provided for in the Budget approved by the Board. No liability otherwise incurred shall be binding on the Society.

"(5) The Board of Direction of the Society may, at 60 days' notice, suspend or disband any Division."

The President explained this proposed By-law and Messrs. Henny, Hogan, Humphrey, and Talbot also spoke, and the matter was left with the understanding that this is to be regarded as the requisite written notice to the Board and that it will come up for final action at the June meeting of the Board.

Proposed Amendments to the By-Laws Regarding Membership

It was reported that A. Travers-Ewell, M. Am. Soc. C. E., in a letter dated March 21st, 1922, suggested that the fourth paragraph of Section 1, of Article I of the By-laws, be changed to read:

"Applications of engineers not resident in Continental United States, and who may be so situated as not to be personally known to five Corporate Members, may be recommended for ballot by five members of the Board of Direction, after having secured evidence sufficient, in their opinion, to show that the applicant is worthy of admission."

Discussion ensued, participated in by Messrs. Davis, Grunsky, Henny, Hogan, Hudson, Humphrey, Marston, and Ridgway.

Director Grunsky stated he would give this as the requisite written notice to the Board of this proposed amendment to the By-laws, and the matter will come up for final action at the June meeting of the Board.

Proposed Amendments to By-Laws Relative to Special Committees

At the meeting of the Board held January 17th, 1922, the Acting Secretary brought up the matter of rules for Special Committees, explaining that the rules as printed in the Year Book in one place provide that "all bills submitted by a Special Committee must bear the approval of its Chairman and Secretary" and, subsequently, under the heading "Expenses" it is provided that: "Extraordinary expenses, such as purchase of instruments, salaries of special employees and traveling expenses, must be specifically authorized and approved by the Chairman of the committee concerned."

The Board decided to simplify this procedure by ruling that all bills should be approved by the Chairman.

It was now reported that as the rules governing Special Committees have been written into the new By-laws from the information in the old Year Book, as given, it would be necessary to change the By-laws to have this take effect.

On motion of Director Humphrey, seconded by Director Hogan and carried, it was decided to regard this as the requisite written notice of the proposed amendment of the paragraph entitled "Funds" of Section 7 of Article IV of the By-Laws, by omitting the words "and Secretary". The matter will come up for final action at the June meeting of the Board.

Suggested Change in Constitution *re* Compounding of Dues

At the meeting of the Board held January 17th, 1922, a letter from L. D. Rights, M. Am. Soc. C. E., dated January 13th, 1922, suggesting a change in the Constitution *re* the compounding of dues was referred to the Executive Committee. The Executive Committee favorably considered the suggestion and instructed the Acting Secretary to formulate a statement for consideration.

As a result, Vice-President Grunsky offered the following suggested amendment to Section 5 of Article IV of the Constitution:

"All future annual dues may be compounded by Corporate Members or Affiliates after having paid dues for five years, in accordance with the schedule presented in the following table:

Elapsed membership, in years.	Corporate Members.		Affiliates.	
	Resident in Dist. No. 1.	Not Resident in Dist. No. 1.	Resident in Dist. No. 1.	Not Resident in Dist. No. 1.
5 to 10	$400	$300	$250	$200
10 to 15	325	250	200	160
15 to 20	250	200	150	120
20 to 25	150	125	100	80
25 to 30	60	50	40	35

"After having paid dues for 30 years, every Corporate Member or Affiliate upon attaining the age of 70 years shall be exempt from the payment of further dues.

"Any Corporate Member or Affiliate having compounded his dues while resident elsewhere than in District No. 1, if he change his residence to District No. 1 shall annually pay the excess of the dues in District No. 1 over those elsewhere, but may compound this annual payment by a lump-sum payment equal to the difference between the figures in the foregoing table, as determined for his years of membership.

"If an Affiliate who has compounded his dues is transferred to Corporate Membership, he shall have the same option of either paying annually, the difference in dues or making a lump-sum payment determined from the figures in the table."

Discussion was participated in by Messrs. Chester, Curtis, Davis, Grunsky, Humphrey, Hunt, and Talbot.

On motion of Director Humphrey, seconded by Director Hogan and carried, this suggested amendment was referred to the Executive Committee for recommendation.

Reports from the Acting Secretary on Various Activities

The following matters were reported for the information of the Board:

Conference on Unification of Abbreviations Used in Engineering Practice:

The Board at its meeting of January 17th, 1922, authorized the President to appoint a representative to such Conference; and it was reported that President Freeman had appointed Mansfield Merriman, M. Am. Soc. C. E., who has accepted.

Sidewalk Alterations to Fifty-seventh Street Property:

These alterations were required by law, and an item ($4 730) was placed in the Budget to cover it. The Board at its meeting of January 19th, 1922, authorized the President to appoint a committee to have full power to contract for this alteration; and it was reported that Messrs. Thaddeus Merriman, E. J. Moore, and James F. Sanborn, appointed as such Committee, had gone into the matter in detail, and the contract had been signed.

Fire Prevention Committee to Study the Tentative Regulations Formulated by the Committee of the National Fire Protection Association and to Cooperate with such Committee:

The Board at this meeting of January 16th, 1922, adopted the report of the Committee on Special Committees in this matter, and the President was empowered to appoint a committee of seven with the restriction that the final report must be made within a year. It was reported that the following members have been appointed as such Committee: Frank W. Hodgman, *Chairman*, John F. Coleman, John Meigs, Rudolph P. Miller, W. Watters Pagon, John Stephen Sewell, and Benjamin Thompson.

American Engineering Standards Committee:

The Board at its meeting of January 18th, 1922, authorized the President to fill the vacancy in the representation of this Society on such Committee, caused by the expiration of the term of H. J. Burt, M. Am. Soc. C. E. It was reported that H. H. Quimby, M. Am. Soc. C. E., was appointed and has accepted.

The Virginia Agricultural and Mechanical College and Polytechnic Institute:

As reply was requested by April 1st, 1922, to the invitation to this Society from the Board of Visitors and Faculty of the College to be represented by an official delegate to the exercises in celebration of the Fiftieth Anniversary of the founding of the College, on May 28th-30th, 1922, at Blacksburg, Va., President Freeman had appointed J. C. Carpenter, M. Am. Soc. C. E., as such delegate, and he has accepted.

The American Association for the Advancement of Science:

The 1923 Meeting of the Association will be held at Boston, Mass., on December 26th-30th, 1922; and President Freeman has appointed George C. Whipple, M. Am. Soc. C. E., to represent the Society at such meeting, and states that he also will attend.

Special Committee on Bridge Design and Construction:

Victor H. Cochrane, M. Am. Soc. C. E., was appointed on such Committee to fill the vacancy caused by the resignation of George H. Pegram, Past-President Am. Soc. C. E., and it was reported that Mr. Cochrane has accepted; also, that A. F. Robinson, M. Am. Soc. C. E., had tendered his resignation under date of February 28th, 1922, and that President Freeman had appointed Otis E. Hovey, M. Am. Soc. C. E., to the vacancy, who has accepted.

Sectional Committee on Unification of Specifications for Wood Cross-Ties and Switch-Ties in Mines as well as Railways:

The Executive Committee at its meeting of February 14th, 1922, authorized the President to appoint a representative of the Society, on such Committee in answer to an invitation which had been received; and it was reported that President Freeman had appointed R. V. Norris, M. Am. Soc. C. E., who has accepted.

Committee on Welded Joints:

The Board at its meeting of January 17th, 1922, appointed Messrs. E. M. T. Ryder and Howard H. George as the Society's representatives on such Committee, and their acceptances were reported.

Special Committee on Electrification of Steam Railways:

The Board at its meeting of January 16th, 1922, empowered the President to appoint such Special Committee to co-operate with similar committees of the other National Societies, provided members of National standing are found willing to serve on such Committee. It was reported that President Freeman had appointed Messrs. Charles F. Loweth, *Chairman,* B. J. Arnold, George Gibbs, George W. Kittredge, E. J. Pearson, Samuel Rea, and Robert Ridgway.

Committee on Technical Activities and Publications:

The Board at its meeting of January 20th, 1922, authorized the appointment of a temporary Special Committee on Technical Activities, and the

amendment of the By-Laws so as to create a Standing Committee on Technical Activities and Publications. The temporary Special Committee on Technical Activities was to consist of the Committee on Publications, together with other members, and the new Standing Committee on Technical Activities and Publications was to replace the Committee on Publications. The President was authorized to appoint such temporary Special Committee on Technical Activities. It was reported that President Freeman had decided that the present Publication Committee could also act on Technical Activities.

In carrying out the instructions of the Board, it was reported that the Publication Committee has approved the appointment of a Sub-Committee on Power, and the Local Sections have been asked to make suggestions as to members for such Committee.

Resignation of W. K. Hatt, M. Am. Soc. C. E., on Joint Committee on Concrete and Reinforced Concrete:

In a letter dated February 2d, 1922, W. K. Hatt, M. Am. Soc. C. E., tendered his resignation as one of the representatives of this Society on the Joint Committee on Concrete and Reinforced Concrete, on account of his duties as Director of the Advisory Board on Highway Research of the Division of Engineering of the National Research Council, and the President has the matter of filling this vacancy under advisement.

Letter of Thanks from Commissioner of Patents:

C. T. Purdy, M. Am. Soc. C. E., in a letter dated March 22d, 1922, enclosed a letter he had received, dated March 17th, 1922, from Commissioner Robertson, of the U. S. Patent Office, expressing the thanks of the 1 016 employees of the Patent Office, for help in effecting the passage of the Patent Office Relief Bill.

Action on Applications for Membership

The following motion was made by Vice-President Hunt, seconded by Past-President Davis and carried:

"*Moved,* That each Director be instructed to take up with each Local Section in his District the responsibility resting upon the sponsors for applicants, impressing upon the individual members the obligation they owe to themselves, the membership at large, and the Society in the premises."

Local Sections Protest Against Re-Districting

The following resolution adopted by the Colorado Section at its meeting of March 27th, 1922, was presented:

"*Whereas,* It appears that the Colorado Section has been included in District 11 of the adopted distribution of members of the American Society of Civil Engineers; and

"*Whereas,* A very large proportion of the members of the proposed district are situated in a group in the extreme southwest corner of the district area far removed from the center of membership of the remainder of the district; and

"*Whereas,* The interests and activities of these members will have little in common with the remainder of the district; and

"*Whereas,* The Colorado Section has heretofore protested against a similar grouping;

"*Be it Resolved:* That the Colorado Section of Members of The American Society of Civil Engineers protests against the grouping as adopted for District 11 and respectfully requests a re-arrangement of the districts in a manner more consistent with the interests and activities of the Local Section."

Vice-President Hunt moved that the Secretary be instructed to write to the Colorado Section that the matter cannot be brought up for action until the January, 1923, meeting, when the re-districting will be taken up again, and that it will be referred to the Committee in charge at that time.

Director Henny suggested that the Colorado Section be asked to propose a re-districting which would be satisfactory to it, and Vice-President Hunt accepted this suggestion, whereupon the motion was duly seconded and carried.

Communications from Director Huber and Secretary Dewell of the San Francisco Section, protesting against the boundary of Districts Nos. 11 and 13, were reported. This matter had been discussed at the morning session when the minutes of the meetings of the Executive Committee were approved, which Committee had authorized the insertion of certain longitude and latitude divisions.

As the Constitution provides for the review of the districting each year by the Board, it was decided that this matter would go over until 1923.

Advisory Committee on Official Water Standards

A letter of March 20th, 1922, was presented from Surgeon General Cumming, of the U. S. Public Health Service, explaining that in order that the Treasury Department Standard for Drinking Water used by common carriers operating in interstate traffic may be made more applicable in accordance with present water supply conditions, an Advisory Committee of scientists capable of passing on official water standards is being formed by the Surgeon General of the Public Health Service, and this Society is invited to designate a representative as a member of such Committee.

On motion of Vice-President Grunsky, seconded by Director Chester, and carried, the President was authorized to appoint such representative.

Conference on Business Training of the Engineer and Engineering Training for Students of Business

This Conference is to be held under the auspices of the Committee on Commercial Engineering, and an invitation which had been received by this Society from Dr. Glen Levin Swiggett, dated March 13th, 1922, inviting this Society to appoint delegates to such Conference, was presented.

On motion of Director Humphrey, duly seconded and carried, the President was authorized to appoint six delegates.

President Freeman subsequently appointed Messrs. John N. Chester, Robert A. Cummings, George S. Davison, Richard Khuen, Jr., E. K. Morse, and Samuel A. Taylor.

Annual Meeting of the American Academy of Political and Social Science

A letter dated February 21st, 1922, was presented from L. S. Rowe, President of the American Academy of Political and Social Science, inviting this Society to appoint three delegates to attend the Annual Meeting of the Academy to be held on May 12th and 13th, 1922, at Philadelphia, Pa., when "The Relation of America to the Rehabilitation of Europe" will be discussed.

On motion of Director Humphrey, seconded by Vice-President Wall and carried, the President was authorized to appoint the three delegates requested.

President Freeman subsequently appointed Messrs. William Easby, Jr., Benjamin Franklin, and Edward B. Temple.

Sequence of Annual Conventions

It was reported that there are now fifteen Districts instead of thirteen. This will change the sequence adopted in 1916* for holding the Annual Conventions of the Society, and the following sequence was suggested for approval:

In 1923,	District	No.	5.	District of Columbia, Maryland, Virginia.
" 1924,	"	"	11.	Arizona, California (south of N. Latitude 36° 30′), Colorado, New Mexico, Utah, Wyoming.
" 1925,	"	"	9.	Indiana, Kentucky, Ohio.
" 1926,	"	"	4.	New Jersey (outside of District No. 1), Delaware, Pennsylvania (east of W. Longitude 78°).
" 1927,	"	"	3.	New York (outside of District No. 1), Quebec, Canada.
" 1928,	"	"	8.	Illinois.
" 1929,	"	"	13.	California (north of N. Latitude 36° 30′), Nevada.
" 1930,	"	"	14.	Missouri, Arkansas, Louisiana.
" 1931,	"	"	7.	Iowa, Michigan, Minnesota, North Dakota, South Dakota, Wisconsin, Manitoba, Canada.
" 1932,	"	"	15.	Nebraska, Kansas, Oklahoma, Texas, Mexico.
" 1933,	"	"	2.	Connecticut (outside of District No. 1), Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, New Brunswick, Canada, Nova Scotia, Canada.
" 1934,	"	"	6.	Pennsylvania (west of W. Longitude 78°), West Virginia, Ontario, Canada.
" 1935,	"	"	12.	Idaho, Montana, Oregon, Washington, Alaska, Alberta, Canada, British Columbia, Canada, Saskatchewan, Canada.
" 1936,	"	"	10.	Alabama, Florida, Georgia, Mississippi, North Carolina, South Carolina, Tennessee.

Discussion on this change was participated in by Messrs. Anderson, Chester, Curtis, and Humphrey.

On motion of Director Humphrey, duly seconded and carried, this sequence was tentatively approved, with the understanding that when the International Engineering Congress is held in Philadelphia, Pa., in 1926, that city will receive preference for the Annual Convention that year.

The Board adjourned at 10:45 P. M., to meet at 10 A. M., April 4th, 1922.

* *Proceedings*, Am. Soc. C. E., November, 1916, p. 699.

April 4th, 1922.—The Board reconvened at 10:15 A. M.; President John R. Freeman in the chair; Elbert M. Chandler, Acting Secretary; and present, also, Messrs. Anderson, Brown, Chester, Curtis, Darrow, Davis, Dyer, Greene, Grunsky, Henny, Hogan, Holland, Huber, Hudson, Humphrey, Hunt, Marston, O'Connor, Pegram, Ridgway, Talbot, Wall, Webster, Winsor, and Yates.

Society Meeting on Pacific Coast and Quarterly Board Meeting

Extended discussion was had as to the date of the 1922 Fall Society Meeting, when a Symposium on Water Power will be held, to be preceded by the Quarterly Board Meeting, which was participated in by Messrs. Anderson, Chester, Curtis, Grunsky, Henny, Hogan, Huber, Humphrey, Marston, Webster, and Winsor, and included a show of hands as to the sense of the Board regarding certain dates.

A letter of February 1st, 1922, was also presented from Secretary Fowler, of the Seattle Section, asking if it would be possible to hold these meetings in Seattle, Wash.

After the offer of several tentative motions, the following motion by Director Humphrey, which was seconded by Director Chester, was carried:

"That the meetings be held the first week in October in San Francisco, California."

Subsequently, at the evening session, Director Huber read a telegram from the San Francisco Section, and moved that the Board meet in San Francisco, on October 2d-3d, 1922, and that the Society meetings follow.

This motion was then seconded by Director Hudson and carried.

On motion of Director Hogan, duly seconded and carried, the date of the Intermediate Board Meeting was changed from September 11th, 1922, to August 28th, 1922.

Pins for Students and Juniors

At the meeting of the Board of January 16th, 1922, the Acting Secretary was instructed to investigate and report on the matter of pins for Student Chapters and Juniors, in accordance with the report of the Committee of the Board on Student Chapters. Two designs were submitted, a small white button with a blue shield superimposed for Juniors and a maroon shield for Students.

Discussion as to these designs was participated in by Messrs. Chester, Davis, Holland, Huber, Hudson, Humphrey, Marston, and Talbot.

Final action was taken in the adoption of a motion by Director Hogan, seconded by Director Marston, approving Design No. 2 as the form of badge for Students and Juniors, with the omission of the word, "Student" and "Junior", centering the shield, and having "American Society of Civil Engineers" printed in full, retaining the circumscribing circle.

On motion of Director Marston, duly seconded and carried, the price of these pins was fixed at $1, and the Acting Secretary was instructed to notify the Student Chapters and publish an announcement in *Proceedings* of the price and date when pins will be available.

Notice was given of a proposed amendment to Article V of the By-laws by adding to Section 7 thereof, Paragraph (*d*): "and the right to wear a badge of design prescribed by the Board of Direction."

This is to be regarded as the requisite written notice to the Board of this proposed amendment to the By-laws, and the matter will come up for final action at the June meeting of the Board.

Federal Charter

The desirability of the Society securing a Federal Charter was discussed by the Board of Direction at its meeting of January 17th, 1922, and this matter was referred to the incoming Board. The incoming Board at its meeting of January 19th, 1922, decided to postpone consideration of this matter. Clemens Herschel, Past-President, Am. Soc. C. E., in a letter dated February 10th, 1922, suggests getting legal advice.

Vice-President Hunt made the following motion, which was seconded by Director Humphrey and carried:

"That the Chair be authorized to appoint a committee of three (Mr. Herschel to be a member thereof) to report to the Board the advantages and disadvantages, and the reasons in favor or against such action."

Local Sections

The proposed Constitution of the Virginia Section was presented to the Board at its meeting of January 17th, 1922, and it was decided that such Constitution would have to be amended to conform to the standard before the Board would approve it.

A letter dated March 1st, 1922, from James F. MacTier, Assoc. M. Am. Soc. C. E., was reported authorizing the necessary changes to make the Constitution of the Section conform to the standard.

On motion of Director Marston, seconded by Vice-President Grunsky, and carried, the Constitution of the Virginia Section was approved.

A petition for authority to form the Lehigh Valley Section signed by twenty-two members, under date of March 31st, 1922, was presented, together with accompanying proposed Constitution, which was reported to be in correct form.

On motion of Director Hudson, duly seconded and carried, the Constitution of the Lehigh Valley Section was approved.

The proposed new Constitution of the Portland Section was presented, it being reported that the Constitution is in correct form, except Article VI, Amendments, which provides that "This Constitution may be amended only by an affirmative vote of two-thirds of all ballots cast by members of the Section." It should contain the clause, "provided the total number of voters shall be not less than a majority of the whole membership."

Director Henny moved the approval of the new Constitution provided it is changed to conform to the standard, which motion was seconded by Vice-President Ridgway and carried.

It was reported that the Constitution of the Iowa Section was approved by the Board of Direction in 1920. At that time the Constitution as approved contained the following article:

"ARTICLE II.—MEMBERSHIP

"*Section 1.*—The membership of the Association shall be restricted to persons who are members of the American Society of Civil Engineers in any grade. All such members resident in Iowa automatically become members of this Association without payment of entrance fee, but should membership in the American Society of Civil Engineers of any person cease from any cause, he shall at the same time cease to be a member of this Association."

This Article which is not in accordance with the standard Constitution, was not especially called to the attention of the Board, and as the Board at its January meeting refused to approve the Constitution of the proposed Virginia Section because it contained a similar provision, the matter is reported to the Board.

There was some discussion by Messrs. Davis, Hogan, Hudson, Humphrey, Marston, and Talbot, the possibility of having Local Sections maintained entirely by funds from the Parent Society being mentioned.

On motion of Director Marston, seconded by Vice-President Grunsky, and carried, the Acting Secretary was instructed to call the attention of the Iowa Section to the necessity for changing its Constitution to conform to the standard.

PLANS TO INCREASE MEMBERSHIP

The following letter dated March 9th, 1922, from President Freeman was presented:

"Since the Society urgently needs more money for expanding beneficial activities and committee work, I recommend for your consideration ways and means for a dignified campaign for increased membership, on the theory that we are doing a worthy engineer a favor by inviting him into the benefits of membership.

"This campaign must be planned and executed very discreetly so that we invite only worthy members and I suggest that it be thought out on the lines of taking our Geographical Directory in our Year Book in hand and address to members selected in each town the suggestion which I have voiced above and ask if he, with his friends, will not constitute a little local committee to investigate the possibility of there being worthy candidates among his neighbors who could be made to see the value to themselves of membership, with its various privileges and opportunities including that of the *Transactions*."

Director Marston moved that the recommendation of President Freeman be carried out.

This motion was seconded by Vice-President Wall, and carried.

Director Brown moved and Vice-President Wall seconded the motion, which was carried, that this action be conveyed to the President and Secretary of each Local Section.

Director Anderson spoke of the desirability of Associate Members forwarding applications for transfer and Messrs. Brown, Darrow, Davis, Henny, Hogan, Humphrey, and Marston also spoke.

Director Humphrey stated that the Philadelphia Section wishes to revise its Constitution, and asked whether the Board would tentatively approve such revision if it conforms to the standard.

Director Hudson made such motion, which was seconded by Director Humphrey, and carried.

Meetings of Presidents of Local Sections

A letter dated February 24th, 1922, was presented from Frank B. Sanborn, Chairman of the Northeastern Section, stating that an informal meeting of the Chairmen of the Sections was held during the 1922 Annual Meeting and that he believes such meetings once or twice a year would develop interest in the Society and help to harmonize its action.

Director Humphrey moved:

"That the Board approve of an annual meeting of the Presidents of Local Sections."

Director Marston, seconded the motion. Messrs. Davis, Henny, Hogan, and Ridgway discussed the matter.

The President declared the motion carried.

John Fritz Medal

A letter dated January 20th, 1922, was presented from Chairman Swasey and Secretary Rand of the John Fritz Medal Board of Award, explaining that the Board has approved the proposal to print and re-issue the John Fritz Medal Book to bring it up to date. Since the first issue of the book, five additional awards have been made of the Medal. The estimated cost is $940, and this Society was asked if it would approve of the issue of such book and bear one-fourth of the cost, not exceeding $250.

At the meeting of the Founder Societies Joint Finance Committee on February 8th, 1922, it was decided to recommend to the governing boards of each Founder Society, that an appropriation of $250 be included in the 1923 Budget as a contribution toward this expense.

Director Humphrey so moved, and this motion was seconded by Vice-President Hunt, and carried.

Local Sections and Federated Societies

A letter dated March 30th, 1922, from Secretary Dewell, of the San Francisco Section, was presented, asking if there would be objection to the Section joining the Federated California Technical Societies.

On motion of Director Humphrey, duly seconded and carried, the Acting Secretary was instructed to inform the San Francisco Section that the Board has no objection to the Local Section joining the federation named.

Report of Committee on Research

Chairman Talbot, of the Committee on Research, made a verbal progress report, and asked for the authorization of the following committees, explaining that others are still under consideration: On Stresses in Structural Steel, Irrigation Hydraulics, Hydraulics Phenomena, Impact in Highway Bridges, and Flood Protection Data.

Discussion was participated in by Messrs. Darrow, Hudson, Humphrey, Marston, and Talbot.

On motion of Past-President Talbot, seconded by Director Hudson, and carried, the President was authorized to appoint these committees.

The report of the Membership Committee was presented.

On motion, duly seconded and carried, the recommendations of this report, which was not read, were adopted as the action of the Board.

The Board adjourned at 10:30 P. M., to meet at 10 A. M., June 19th, 1922, at Portsmouth, N. H.

ADDRESS OF WELCOME AT THE MEETING OF THE SOCIETY, DAYTON, OHIO, APRIL 5TH, 1922

By Col. E. A. Deeds.*

It is indeed a great pleasure to be here this morning. It is a great day for Dayton, and it gives me the greatest pleasure to welcome you in the name of our Engineers' Club. We have 575 members of this organization residing in the Miami Valley. You are doing us a great honor to come here and be with us. Your presence will encourage us much and be a great inspiration to the younger members of the organization. This meeting will give us a broader vision of our opportunities and duties as a Club.

Again, in the name of the Miami Conservancy District and in the name of this Miami Valley which owes so much to you and your organization, I want to welcome you.

Those of us who have grown up in this industrial valley as mechanical and electrical engineers, did not know much about the civil engineering organization prior to the flood; but we do know something of your organization now, because of the men who came into this Valley to solve this great flood problem. The finest group of men who ever came into the Miami Valley, came in for this purpose. They have endeared themselves in the hearts of the people, they have given your organization a standing and a reputation here which are enviable.

When we first started on this work, we had little realization of what the problem was. We had never seen the civil engineering problems being met in the larger way. When we started this work, we started it hesitantly, but seriously. We studied the problem and found that there was a solution. When this was found, we went to work to bring it about. When it came time to start construction, we started it without any demonstration. When the first dragline was on the ground and had steam up, we started to dig.

We have no plans for any formal demonstration when the work is finally finished. We propose to finish this work and turn it over to the coming generations as quietly as it was begun. If there is to be any formal demonstration, we might consider your meeting as celebrating this event. And what could be more appropriate? We are to-day honored with the presence of the American Society of Civil Engineers whose experience and personnel have made this great work possible. We then, to-day, formally dedicate this great project and with your blessing it goes on its great mission of mercy for centuries to come.

I hope that this meeting in Dayton (and we feel complimented that your first meeting away from New York City is here with us), as you devote time to the study of the flood problems, will be only the beginning of a number of such meetings, at which is discussed this most vital subject.

Any information or experience we have here that may be helpful to you in the future, is at your disposal. We ourselves are at your disposal, any

* Chairman, Board of Directors, Miami Conservancy Dist., Dayton, Ohio.

time, anywhere, to assist in the great work of flood control. We are indebted to your organization for making this great work possible and will be ever ready to reciprocate. To this I can only add again our most hearty welcome.

REPLY TO ADDRESS OF WELCOME AT THE MEETING OF THE SOCIETY, DAYTON, OHIO, APRIL 5TH, 1922

By John R. Freeman, President, Am. Soc. C. E.

Mr. Chairman and Fellow Engineers: We of the American Society of Civil Engineers are most appreciative of the kind welcome that has been given us. This is the third notable welcome we have had since the Board of Direction of the Society first came in advance to Dayton, and all have been most hearty and genuine and have made us feel thoroughly at home.

I made my response to the first addresses of welcome by Governor Cox, Commissioner Deeds, and Chief Engineers Morgan and Paul at the Dayton Engineers' Club, and I do not know that I can do better now than to repeat some of the things I said then.

I said that of all the studies of flood problems that I had known in any city of the world, I had never known of one that was taken hold of with more vision, broader horizon, and a finer scientific spirit. Very often after a great flood there is a spasmodic investigation, and the curbstone engineers, the citizens' committees, and various people all tell what to do; there is great temporary excitement and a promise of great things, but very often all of that immediate interest evaporates, without leaving much behind.

This case of the Miami Conservancy, I think, stands out among all others in American cities, in the prompt way in which your committees and your engineers began their work, and the scientific way in which they "made haste slowly" in the early stages. The scientific studies that were made of flood problems all over the United States—the studies of rainfall and run-off and the mathematical studies of means for dissipating the energy that would be generated in the discharge from these great conservancy dams—were made with a thoroughness that has aroused the admiration of engineers throughout all this country.

Usually, it is the experience that all such good things in administration originate with a small group of men, and sometimes they originate largely with one man. In this work, most of us have found out who the one man was. One might say, in the words of a famous epitaph, "If you would see his monument look about you"—for the monument of Col. Deeds is all around you, up and down this Miami River and in this club house within which we are meeting. In talking with Col. Deeds, I remarked on the pleasure it must give him to see the happiness that he and his partner had brought into the lives of all these young men meeting week after week in this admirable

club house; and he replied, "One can have a lot of enjoyment in being his own executor". I hope he will reap the full measure of pleasure that should come for all these good works.

The American Society of Civil Engineers is just seventy years old this year. There is an older organization which, as you know, is the most dignified body of its kind in the world—the Institution of Civil Engineers in London. In the charter of that great Institution the work of the civil engineer is defined as directing "the great forces in Nature for the benefit and convenience of man". There certainly are few greater forces in Nature than the flood which came down this Valley; and your engineers seem to have been justifying the old definition of the Profession by directing the Miami floods so that when one comes again, it will not come through the main streets of Dayton.

There will be benefits from all this work far more widespread and lasting than those to the City of Dayton alone, from the preliminary scientific studies to which I have already alluded, and from the bulletins that have been published of the progress of your work from month to month. Those preliminary memoirs and bulletins are filed in the libraries and offices of engineers all over this country, and far beyond this country, as may be illustrated by the fact that, among others, I subscribed for extra copies of those bulletins and sent them to far-off China, where I know they will do great good.

Among the final work here was one of the most beautiful tributes of the Dayton Conservancy engineers to the good cause of flood protection all over the world, in the eight monographs that have been published, giving the results of the various scientific studies made in the course of the designing and building of these works.

That broad spirit of loyalty to the Profession and the good of mankind has been shown through everything, and that is why this Miami Conservancy work is going to be of far more value and more far-reaching than the Miami Valley.

We have, as Col. Deeds has said, great need for the study of problems of protection against floods in many localities. Those who have eyes trained to read the story in the gorges and ravines and in the face of Nature itself, can see plenty of evidence that, from time to time, these great floods and cloudbursts occur here, there, and almost everywhere, throughout this broad country of ours. Fortunately, they do not come very often. Many of the valleys and ravines that we see, could have been sculptured in no other way than by one of these great storms, and when one looks closely and steadfastly, it is surprising how full a record one can see of these great floods—all the warning that man needs.

There is an interesting instance of the late James B. Francis, Past-President, Am. Soc. C. E., searching and finding such a warning. In his early years, Mr. Francis came into large responsibilities in the management of the water power company, at Lowell, Mass., on the Merrimac, and in looking around he detected marks of a great flood long past. He then investigated the traditions of early settlers in the valley, and tried to find accurate information, by systematic study, about the worst that might happen from such a

flood if it should be repeated under present conditions of building and river obstruction.

It is surprising the number of ancient marks that can be found in almost any valley, if a systematic canvass of every farmhouse is made. I have been astonished after starting out on a search of that kind, where there seemed to be very little reliable information, to find after we had completed a house-to-house canvass in the valley, and had run a line of levels over all the flood marks shown by old residents, that we had the finest kind of a record; and I believe that a good and sufficient record for purposes of warning can be found in almost all the valleys subject to these floods. The warning signals are there, if only we have the eyes to see them and will take the time to look for them.

Returning to this case of Mr. Francis at Lowell, he found records of a flood greater than that within the memory of the oldest inhabitants, and having charge of the works of the water power company along the river, and the land on which to build, he forthwith proceeded quietly to build a dike and a great flood-restraining gate across the old Pawtucket Canal. The work was conspicuous and excited comment, not only among his own directors, but among the citizens. The dike and gate were often spoken of as "Francis' Folly". They stood there, apparently absolutely useless, as I remember the story, for something like twenty years. There was no mechanism for hoisting this gate—merely a simple mechanism for dropping it, which consisted of a large iron suspension stirrup with a cold-chisel and a hammer placed near-by.

Finally, suddenly, the flood came—greater than any within the memory of man then living—that iron strap was cut, the gate fell, and Lowell was saved from any such inundation as was experienced here in Dayton. The gate and dike no longer were called "Francis' Folly", and to atone for past misjudgment, the grateful citizens presented Mr. Francis with a beautiful set of solid silver table ware. All over this country opportunities exist for similar beneficent work in finding out what is likely to happen before it actually does happen.

For a great many years, I was connected with a water power company which maintained records of floods and continuously studied the flow of water on the river. I had been very much interested in the great rainfall of October, 1869, and of the flood which this caused on the Merrimac River. The story of this had been compiled by Mr. Francis. In that flood, there was just about the same depth of rainfall that you had here in the Miami Valley in 1913. The storm of 1869 swept over an area of something like 10 000 sq. miles, the Merrimac River rose to a depth of 10 ft. over the crest of the Lawrence Dam, and had a discharge of 100 000 sec-ft. at the peak of the flood.

Later, in 1878, I had occasion to follow the course of another flood at the same dam, which rose nearly to the same height and was caused by a rainfall of only one-half the amount that had fallen in the earlier flood. In the earlier flood, there had been a rainfall of 10 in. In this later flood, it was 4.78 in., as I now remember, less than one-half the rainfall of the earlier one. Yet it produced a flood of equal size. The reason was that the first flood came

when the ground was absorptive, and the second flood came when the ground was frozen and the water nearly all ran off. Conceive of the rainfall of 10 in. on non-absorptive ground, and you have a condition worth thinking about.

In coming to Dayton for this meeting, we have three special objects—to learn what we can about your great flood, to see the works that you have built for preventing disaster from even a greater flood, and to hold this symposium and get together all the data that we conveniently can of similar flood problems, with a view to awakening interest all over this land, and preventing such disasters as that which swept down this Valley.

FACTORS IN ENGINEERING ACCOMPLISHMENT, THE MIAMI CONSERVANCY PROJECT

Address by Arthur E. Morgan,* M. Am. Soc. C. E., at the Meeting of the Society, Dayton, Ohio, April 5th, 1922.

It is scarcely necessary to say that the accomplishment of the Miami flood-control project was not just an engineering undertaking. The people of Dayton determined not to have a repetition of the disaster of 1913, and it was their will, their courage, and their determination that are primarily responsible for the results that have been achieved. Certain men stand out from the mass—a number of men—who gave themselves so unreservedly and so effectively that whenever I think of flood control I think of them.

There is Mr. John H. Patterson who, while the flood was occurring and afterward, put into the situation his resources, his tremendous energy, and his virility, to great effect. There is also Mr. Adam Schantz, who stood back of this work from the very beginning until his death in 1921.

Possibly, Col. E. A. Deeds has been the most active of any one in the whole undertaking. He has been behind this work with his vigor and his energy, and it is no exaggeration to say that the work of the Miami Conservancy District never would have been brought to fruition, but for the untiring, persistent, enthusiastic energy of Col. Deeds. After the work had been going on for somewhat more than two years, I was out of touch with it for about a month on account of illness. It so happened that at the same time Col. Deeds was away from the scene of action. The first day that I was able to sit up, I had a visit from three of the men who had charge of affairs here, who came to say that it was not wise longer to go ahead with the preparations as we were doing; there was no use in going ahead; that active preparation should cease; and that the engineers should be dismissed and the work practically stopped.

On account of my condition, I did not have much energy, so about all I could do at that time was to temporize and say that there were a few odds and ends that would have to be gathered together and that the engineers ought to be kept a month longer. They were kept a month longer and the evil day was staved off; by that time Col. Deeds had returned and put back into the situation that energy and virility that carried the organization over what might be termed the peak of depression.

Col. Deeds is going to tell you of the public connections of the Project, and Charles H. Paul, M. Am. Soc. C. E., will describe what has been done. I am going to tell you not what was done on this Project, but how it was done. If I were to pick a patron saint for engineers, I think I would take the deacon who made the one-horse shay. You know what he did. He worked out that design so that there was no part of the whole structure that was not exactly as strong or exactly as well proportioned as every other part. You know Holmes' poem and how the old shay ran, "A hundred years to a day", and, as the deacon was riding to church, it crumbled and he found him-

* Pres., Dayton Morgan Eng. Co.; formerly Chf. Engr., The Miami Conservancy Dist., Dayton, Ohio.

self sitting in a little heap of dust. It was so perfectly proportioned that there was no element in it stronger or weaker than any other.

That is the ideal of engineering—to use the total available resources in such a manner that every item of those resources is used where it will count the most, and also to consider every factor that enters into the problem so that in no case an undue amount of attention has been given to one factor to the neglect of some other. It is that perspective, that proportioning of the job, which makes engineering work effective, that habit of including all the factors with their true relative importance accredited to them.

That is the "a, b, c", in the technical phases of engineering, but it is no less true when every factor that enters into the accomplishment of a purpose is considered. Here, at Dayton, we wanted to prevent floods. There were many factors involved; some of them were purely technical matters that could be worked out by research and in no other way. Some were matters of routine design, but there were many other elements just as important, the omission of which would have wrecked the job just as surely and yet they were not ordinarily considered as engineering. About the first job that I undertook, after coming here, was to make a catalog of the factors that would enter into the problem, saying to myself, "This element must be considered if we are to succeed; that element may loom large, and that other one may have an important bearing", and to endeavor to see that there was no element in the whole that was not given consideration in proportion to its importance. In meeting the demands of that catalog or schedule, much of the work went far afield from what is ordinarily considered as technical engineering.

I am going to mention some of the varied factors that affected the plans, because when one seeks the final aim of engineering, it is found to be not design, not research, but accomplishment; and every factor that affects accomplishment must have attention to insure success. If the wife of the concrete inspector has indigestion and worries him so that he neglects his work, the results may be just as fundamental and just as far-reaching as technical errors in the structural design. Whatever factor enters into the completion of the job is worth consideration.

When I first came to Dayton, there were some undertakings that had to be initiated before such a catalog or such an inventory could be made. In the first place, it was necessary to develop patience. Every one wanted to start construction at once. Those in charge of the work were told that in three months there must be steam shovels in the river. The building of an attitude of restraint and of expectation of a long siege of preparation was one of the first essentials. Unless the people of the Valley could be made to see the need for a period of preparation, then fine work in research and planning would mean nothing because, losing patience, they would take up some quick method of relief.

Another of the first things that had to be undertaken was to persuade the people of the Valley that their way out was to help themselves. Those of you who have been through many such projects know well that the pursuit of Federal appropriations for such an undertaking is like chasing a will-o'-the-wisp, but whenever a big flood-control problem appears, the first appeal

is to the Government, therefore, one of the first jobs at Dayton was to get the people to see that waiting for Federal relief would be long drawn out and possibly futile in the end, and that the way for them to get results was to help themselves. That was a point of view that had to be developed quickly and effectively, so that no one would have to start off on futile trips to Washington and dissipate his energies through seeking Federal aid.

Another of the immediate necessities was that of finance. When the suggestion was made that adequate resources for preliminary investigations were fundamental, the people came back with a public contribution of $2 150 000. That was one of the most remarkable exhibitions of civic interest I have even seen, and the availability of that fund had very much to do with the thoroughness with which preparations for the job could be made.

It was then necessary immediately to make permanent the record of the flood—the record the flood had made of itself. The first parties, placed in the field within about six weeks after the flood and within three or four days after the job was started, were concerned with preserving, in accurate, tangible form, every record of importance that the flood had left, so that at later times the engineers could construct hydrographs and discharge curves and compile their data from accurate records. In that pursuit, I was often reminded of Münsterberg's book on "Evidence"—how possible it is for people, in time of stress to see what is not so.

Then began the organization of thorough-going field work. For that, O. N. Floyd, M. Am. Soc. C. E., had been brought from a project in the swamps of Mississippi. He has lived through this job to the completion of one of the biggest units. During that first season much of the burden of the field surveys devolved on him.

As the catalog of the factors that would enter into the accomplishment of our purpose was begun, the need was immediately felt of certain technical information of greater accuracy than had hitherto been available. For instance, every man present, who works on flood control, feels keenly the lack of knowledge of rainfall. Engineers must have all the information available, where the issues are as great as those on this project. A knowledge of probabilities and of the relations of time and depth and area in rainfall was the chief need. Therefore, one of the first undertakings of the early weeks of preparation was to outline a research in rainfall. The final results were issued in one of the technical reports, previously mentioned. It was thought that research would be finished in about a year, but it took between four and five years. If the immensity of the task had been realized, it is questionable whether we would have had the courage to start it.

Then, the lack of knowledge of run-off was realized. During the first few weeks, a line of investigations was formulated, that was continued for more than five years.

The engineers were aware, as all engineers are, of the somewhat indefiniteness of the reliability of stream-flow formulas and, again, a line of investigation was formulated—the men were started off before the mud had been removed from the streets of Dayton and that investigation, after three or four years, gave a sound basis for conclusions.

These investigations must be started quickly, and they were. The results that have been presented in the technical reports have followed some very fine research. To a large extent, the merit in those technical reports must be credited to S. M. Woodward, M. Am. Soc. C. E., who spent a large part of his time here for several years. To a great extent, the remainder of the organization was his helpers. The analysis of new problems that had not been made before, is largely the work of and is due to the insight of Mr. Woodward, and I believe the reputation of those reports will increase as years pass, and that the Miami Conservancy District will continue to profit by the insight that he brought to that part of the job. Among his associates, Messrs. Houk, Bock, Riegel, Matthes, and others, made effective contributions.

I always imagined that if one could delve into the archives of European engineering libraries, one would find a great reservoir of information on hydraulics and flood control. To make sure that no valuable data were being overlooked, a survey of European flood-control literature was undertaken. Kenneth Grant, M. Am. Soc. C. E., conducted that work admirably, spending about two years in a search of European flood-control literature which might throw light on the problems at Dayton.

It was soon realized that the work would have to be paid for by special assessments, so the problem of appraising benefits and damages was taken up. All those lines of investigation were started within a comparatively few weeks after we came to Dayton and had made up the little catalog of factors that would enter into the situation.

Before the work had proceeded far, it became apparent that there was no legal machinery in this State which would adequately handle such a project. Much of the research could be delegated, but that was a job where delegation did not work out well and I personally examined, sentence by sentence, practically every flood-control statute in the United States and Europe, trying to find reflected therein, the record of any experience that might be met here. The Ohio Conservancy law, under which the work is being done, is primarily a law drafted by engineers. There is scarcely a working provision in the whole law, either as to the general structure or to the detailed procedure, that is not built from an engineering standpoint and from engineering experience. When that was completed, we had the substance of a code. The attorneys of the Flood Prevention Committee took this draft and handled it in an admirable manner, checking it, clause by clause and word by word, bringing it into the legal requirements of the State and Federal Constitutions. After that, it was similarly dealt with by bond attorneys and finally emerged, after many conferences (not all of them entirely free from argument), in an instrument that has served its purpose almost without fault during this period of preparation and construction.

While these various lines of work were being carried on, it was obvious, as indeed it had been since the start, that no job like this would carry through except as it had the support of the public. We would be leaving unused our greatest assets and we would be building up possibly our greatest liabilities if we should leave, uninformed, the public that must support this undertaking and, therefore, while we were preparing the plans, while we were working out the

project, we were informing the public, we were talking at meetings, we were writing up various features of the work, and in every way possible endeavoring to have the public understand and have an insight into the job. In that particular, I believe we failed possibly more seriously than anywhere else in the progress of the Conservancy undertaking. Time after time, I brought men here from New York City, Boston, or Chicago, and I would think, "Now, I have found a man who with dignity and accuracy and yet in a popular manner, can present our project to the people". Sometimes I would find the technical ability and the drive; sometimes the popular appeal, although lacking in accuracy and dignity of expression, but not until we were actually on construction did we find a man who could be our instrument in presenting this job to the people. I believe that if a clear, simple interpretation of the job could have been made, much of the opposition we fought so hard to overcome in the territory to the north of Dayton would have been obviated. There was a place in these threads which we were trying to weave into a finished fabric, where a thread was missing, and it troubled us through the whole progress of the work.

More than that, here at Dayton where the burden of this work had to be carried, it was necessary to build in the public mind an expectation of success. That the job was possible of accomplishment is evidenced by the fact that it is done; but the possibility depended quite largely on the attitude of mind of the people of Dayton. If they believed it could be done, there was more likelihood of its being done than if they believed it impossible, and the job of building an expectation of success was an element just as vital in the progress of this work as the design of the concrete conduits. If the expectation of a successful issue of the undertaking was lacking, the way of its promoters was to be very hard, if not impossible.

I have mentioned the time when work was ordered to be stopped, which indicates how narrow a margin of courage and support they had. Col. Deeds recently remarked that if people had known, when they started on this job, the obstacles and the difficulties to be overcome, they would not have started. Why should they have known? If any one should start out in life knowing all the troubles ahead of him, he probably would want to quit before he began. It was necessary to mobilize and integrate all the resources of expectation of success, all the resources of optimism that this community possessed, and not to develop, any more than was necessary, the attitude of discouragement and of seeing troubles in the future. Therefore, it was not entirely without guile that we failed to paint pictures of future difficulties.

In October, 1913, after about five months of work, a plan had been outlined, which plan is the general method used in construction. During the development of those plans, we had the support and the assistance of a board of consulting engineers, Mr. Woodward whom I have mentioned, Daniel W. Mead of Madison, Wis., and John W. Alvord, of Chicago, Ill., Members, Am. Soc. C. E. They were of tremendous help, not only in giving us the courage of our convictions, but also in supporting us before the public.

When it was decided to build dams, we had even a more serious problem before us. If one will think back ten years and consider the attitude of Amer-

ican engineers on reservoir control for floods, one will find it was quite uniformly hostile. A few people were promoting a favorable attitude, but even that promotion was sometimes unfortunate. On the Lower Mississippi, there had been a long, hard fight over the question of reservoirs or levees. The use of levees was right; the Army engineers knew it was right—they had fought for their use, and in that fight reservoirs *in toto* were pretty well discredited. While we were struggling at Dayton to build up the expectations of success and this confidence in the job, I recall that the Army engineers came here for a brief examination and then issued a printed report to the affect that it would be an unfortunate decision to undertake relief by the construction of dams. Under the circumstances, that report was not a very stimulating incident.

As a matter of fact, we faced an adverse engineering opinion in this country, built up largely because of the opposition to reservoirs where they were in reality entirely impracticable, and carried over into fields where the question had not been carefully examined. With this widespread attitude of opposition to flood control by the building of dams, it was necessary if we were to see this job through, to bring the substantial engineering opinion of the country to our support. Here, was another factor; another thread in the fabric, that was as important as any other. We began to bring in these other engineers. It was remarked facetiously that they were brought in large groups, but here and there we brought in representative men, who carried with them the respect of the engineers of the country, and had them go over the plans as critically as they might, until their own questions had been settled and until they were ready to approve the plans definitely. There came gradually a certain approval and support from the engineers of the country, that could not have become ours without very careful preparation.

One of that group of consultants was the late Gen. H. M. Chittenden, U. S. A. (*Retired*), M. Am. Soc. C. E. He had fought valiantly against reservoir control where it was not practicable. His works were generally quoted over the United States as authority for the position that reservoir control was impracticable. That being the case, it was thought well to send for him. He came and worked faithfully and long and hard. He examined the data and kept the office force busy supplying him with information. He seemed indefatigable, and when he had finally satisfied himself as to the correctness of our position we had nowhere a more enthusiastic supporter. Gen. Chittenden gave much of the energy of his later years in helping us to gain the good will and the approval of the Engineering Profession. If we had failed to bring that thread into the weaving, I question whether we would have been successful.

When the conclusion was reached that a series of dams must be constructed here, the job began to take more or less specific form. One could begin to see what kind of an organization would be required. One could see that whoever came here, would do well to have a period of apprenticeship, and, therefore, we began to select the permanent personnel, which was done with a great deal of care. I feel more proud of that than any other feature of the work. I think the results speak for themselves. The success of the Miami Conservancy Project is largely built around the success achieved in

selecting this group of men. There was developed not only ability, but loyalty. Of the division engineers on the five dams and the river improvement channels at Dayton and below, there were seven or eight who came on the job shortly after the general type of protection was decided. Of those, Alfred B. Mayhew, Assoc. M. Am. Soc. C. E., was drowned during the progress of the work. We, his friends, pay tribute to his fine loyalty and solid ability. All the others have stayed through these eight years and have seen the job to completion. That, I think, is admirable evidence of interest and loyalty. I know that some of those men were tempted elsewhere at salaries that we did not meet.

So the work was continued until the summer of 1915, when we were able to organize the Conservancy District. About that time, Mr. Mead took charge of the work for about five months while I was recuperating from illness. His work was of inestimable value. In the latter months of 1915, we located Mr. Paul. That was one of the important events in the development of the conservancy work. It had reached a point where the general design was about completed, where the general features were about determined, where the various investigations were under way, but where we needed to "get down to brass tacks", where specific design was needed. After being here for six months or a year—I have forgotten how long—getting acquainted with the work, Mr. Paul became Assistant Chief Engineer and his administrative ability with his judgment and common sense that he got over there in the Massachusetts hills somewhere, has been one of the mainstays of the Conservancy District.

Little by little, all these threads of the fabric were drawn together, until a pretty well developed design had been prepared. Here and there, a thread slipped, as I mentioned in the case of publicity. The fact that we did not slip very often was due to the personnel. I might say that it was clear from the beginning—from near the beginning, at least—that this was not a one-man job. If it could be done, it was because it could be delegated, and it was the fact that it was delegated—that no one tried to do all of it himself—that makes it a real job. The work Mr. Woodward did in technical research will stand, I believe—some of it—for 100 years as a classic in its line, because we got him on the job and let him alone. The work of the design of the structures was handled by Walter M. Smith, M. Am. Soc. C. E., another piece of delegation in which we did not fail.

In the case of the division engineers there was also delegation. I wish that time permitted me to give credit to these, admirable men, one by one. As soon as somebody would show his head and carry a bigger load, he got it. When Mr. Paul came on the job, we started to load him up to see how much he would take, but we never got him loaded to that point. I do not know yet how much he can carry. Little by little that delegation of engineering functions became fairly complete. Then, in the latter part of 1917, we began to need delegation of another kind. We had reached the point where we were ready to begin construction, and for some months we had contractors come and consult with us as to how they would do the job in the event they should be successful bidders; as to how the job ought to be handled. They were here presumably getting ready to bid, but in reality they were taking a civil

service examination. Some of them approached the work with a keenness and a sureness that was admirable, whereas others fumbled and said, "We have a way to do this". In this stream of men that flowed through the office, one man came whose incisiveness of mind, definiteness of perception, and keenness of imagination and understanding made a tremendous impression on us. The result was that when we looked for some one to take over the burden of construction, we picked Mr. Locker and we have had no regrets. It has been one of the triumphs of our progress that we found Mr. Locker. He did not come here for the income, but for sportsmanship, and he did his work with the spirit of a sportsman and not with the spirit of one who works for gain. The integrity of these structures will be a monument to him and his assistants long after we are gone.

When it came to the construction, we again had to extend this catalog of factors that entered in the situation. We had to consider what makes a good job. Partly, it is numbers of men and skill, but there are other factors. We believe that when a man lives comfortably, when the stress of his living environment is taken away, he can work more effectively. Therefore, we worked out housing for these people and built little villages where the environment was convenient and pleasant, where the women folks could have water in their houses and grass in the front yards and where there could be set down a normal, decent American environment. Having that, we were able to secure a different type of man than if there had been only shacks. That was perhaps particularly true of the directive forces. The turnover in the forces to which we furnished housing, was very small indeed. The effect of other conditions on them was considered; schooling for the children was furnished. It seems like a "high-brow" thing to do, or visionary, and yet when you get close to a man's heart, when you get close to his interests, you will find that the conditions under which his children are growing up are vital to him and by furnishing, in those communities, high-grade school facilities for the children, we were touching a real factor that entered into the success of the project. Their health conditions were considered; decent water supplies were furnished. Dr. Smalley, the physician, has been a genius. (I wish there were another place in the country where he could drop in, because he fits that kind of a job.) If a family was out of order, he put it in shape; if there was discouragement there, he cleared it up. He lifted those people along and kept up their courage and their spirits. I think he was just as effective a unit in the accomplishment of the purpose as the man who did the designing in the office. In estimating the factors that enter into the successful accomplishment of this project, we tried to make an environment in which a man could work effectively and in comfort and contentment.

Mr. Paul's work on the Arrowrock Dam had given him a mastery of administrative methods that we leaned on very heavily, indeed. The organization of the accounting department, the traffic work, the warehouses, etc., was Mr. Paul's work and without that we would have been very lame indeed.

In brief, this is how we did the job. Little by little, we found here and there a by-product we could get. The technical reports that have been issued may not seem to have any bearing on the dams—the dams will not stand any

longer, perhaps, because those reports are issued—but it seemed fitting, if we could extend and expand the range of information, that it was our duty to make that information available rather than keep it in our own archives; and that we should in some degree repay the great debt we owed to pioneers in engineering research.

There is one piece of work I did not mention in our technical researches, that should be mentioned. We had a tremendous job in working out the correlation of all the factors of an engineering design. As Col. Deeds often remarks, we would change one element in one of these dams or channels, and it affected the whole structure; just as when you punch a jelly-fish, it trembles all over. Every change affected every other change, and here we labored year after year—the whole force of seventy-five engineers—to get the final economical combination of all those variables. This was finally accomplished by a sort of rule-of-thumb method and we were very proud of that accomplishment. We were about through, when we wrote a technical report on it to describe how we did it. The proof was handed to one of the younger engineers, E. W. Lane, Assoc. M. Am. Soc. C. E., who brought it back a month or two later, with a clean-cut method of arriving at the ultimate economy of design by a process of analysis that would have saved many weary months of work and a great many thousands of dollars. This brilliant piece of work on the part of Mr. Lane will, I believe, have decided value in the future. Mr. Lane is now in charge of some work in China, and I can see there the same acumen and keenness in approaching his problem, that was shown on this research job.

One of our main undertakings when we started out here was to find men who could do this thing, to find men who had the ability for each separate responsibility and, little by little, to get the job delegated so that it would be well done. That delegation was effective. It was so effective that I have been for the past year or two becoming more and more a supernumerary. It is almost a year now since I ceased to have any real directing function and on September 1st, 1921, I resigned. Mr. Paul has entered into the work with a thoroughness and effectiveness such as the organization never saw before, and he is finishing it with a credit that is not apt to be exaggerated.

ITEMS OF INTEREST

The Committee on Publications will be glad to receive communications of general interest to the Society, and will consider them for publication in *Proceedings* in "Items of Interest". This is intended to cover letters or suggestions from our membership concerning matters which are not of a technical character. Such communications, however, must not be controversial or commercial.

Unemployment Situation Is Improving

In a statement describing the unemployment situation for the past three months, Mr. Walter V. Brown, Manager of the Federated American Engineering Societies Employment Service, said that a period of marked betterment had set in.

For the last three months the outlook has grown more hopeful. Increased employment opportunities prevail rather uniformly in the major branches of engineering. The Unemployment Service has placed 870 men in engineering positions since January 1st, 1922. At present, from ten to fifteen professional engineers a day are finding places.

The demand for radio apparatus is exceeding the supply, and is likely to exercise a growing influence on unemployment conditions. The Executive Board of the American Engineering Council, of which Dean Mortimer E. Cooley, M. Am. Soc. C. E., of the University of Michigan, is President, has authorized the appointment of a special committee to investigate conditions among engineers. Dean Cooley stated that it was the purpose to formulate a permanent and constructive engineering policy as to unemployment.

The re-opening of the copper mines, and the relief which the mining industry in general is beginning to experience, has not produced any marked effect on the unemployment situation among mining engineers. Most of the calls for mining engineers have come from South American countries, to which twenty men have been sent recently to fill responsible and generally remunerative positions.

About 3 000 applications are now on file at the Unemployment Service. This number has not increased during the last month, as it had during previous months. The Volunteer Committee of Engineers to aid in finding jobs for members of the Profession has been increased to thirty-five members, working in the Metropolitan District. Similar committees are at work in other cities of the United States. Mr. W. N. Gately who is active in the local volunteer work, states that the volunteers are making marked progress in extending the scope of the engineer to new fields.

Suggestions from the Voluntary Committee of the Employment Service

The experience gained by interviewing hundreds of employers and thousands of employees seems to prove that the average job hunter passes through three stages before making a new connection.

The first may be likened to that of a chicken which has recently been deprived of its head. First, comes the severing blow of discharge, followed quickly by a wild spattering of messy letters, fit only for the waste basket, and a mad aimless rushing hither and thither after jobs for which he is unfitted. Should any one dare to offer the kindly suggestion that he is reaching for something beyond his grasp, the applicant sees a diabolical attempt to keep him out of work and bull-headedly insists on having his way, blindly ignoring the fact that he is wasting his time and hurting the Bureau.

Meeting with no success, he is overcome with an enervating feeling of maudlin self-pity, and proceeds to give an excellent imitation of Sir Isaac Newton discovering the law of gravity. Although the achievements of great scientists are always worthy of imitation by engineers, there is little chance these days of a job falling into the lap of any man. At this stage, he spends a goodly part of his time in composing bitter arraignments of the inefficiencies of the Bureau (unmindful, perhaps, of the fact that his contribution toward its support amounts to just 25 cents per year), and is quite firmly convinced that the hand of both God and man is turned against him.

He finally reaches the third stage where he decides to quit imitating the ostrich, withdraws his head from the sand of ignorance and personal prejudice, and faces the cold hard facts. Now, something can be done to help him.

To get a job one must sell one's services. Unfortunately, the prospect of having to go out and attempt a sale seems to throw most engineers into a blind unreasoning panic, owing, doubtless, to a childlike acceptance of that most fallacious, although generally accepted, statement that an engineer cannot make a good salesman. Surely a man who understands human nature, knows his goods, thoroughly believes in them, and displays a reasonable amount of enthusiasm in presenting them, should stand a good chance of making a sale. The trouble with the engineering job hunter is that he does not know his goods, consequently, he has not a strong belief in them and instead of presenting them with a show of sincere enthusiasm, tries to cover these defects with a bluff, appearing, therefore, either as a "know it all" or a charity seeker.

When an employer desires a man to fill a specific opening, he always has a well defined idea of the kind of man he wants, and that applicant is successful who most closely approximates that ideal. True it is that one occasionally meets a man who seems not to know what he wants—and this is really the easiest type of man to deal with if the applicant knows and believes in himself. The employer's nebulous ideas can often be crystallized into a form according almost exactly with the qualifications of the applicant. Unfortunately, most applicants seek merely a certain salary and are ready to take almost any kind of a job which will pay it. Hence, to a prospective employer they appear weak, doubtful of their own capabilities, and create a negative

impression on him. Remember, always, that when a man is hired, a contract is made and a contract has been well defined as "a meeting of two or more minds". How, then, can two minds meet, when only one of them has a well defined set of ideas? Therefore, the first thing for a man to do is to draw up a detailed list of his qualifications—personal, educational, practical. Let him play fair with himself and note both strong and weak points. Here, he begins to make progress, for ambition will force every normal man to seek remedies as soon as he recognizes his weaknesses. Next, he should combine this detailed list of qualifications into a clear, concise, forceful experience record which will show him in the best light possible. This is the hardest part of the whole task and will require not an hour, but more often days of hard, consistent, even painful effort. When properly done, however, it creates a wonderful feeling of confidence, and gives him a sharply defined idea of his size as pertaining to any job he seeks. As a result, he no longer wastes his time and efforts in madly chasing impossible jobs, but settles down to a determined and a frequently much more successful hunt for a job within his capabilities.

Incidentally, this is an ideal time to take some thought of the future and decide what one would like to be ten or twenty years from now, thus gaining an idea of how far one has progressed along the desired path, and what steps must still be taken to attain the goal. One should set up a high standard, but not an impossible one; and what that may be, each man must determine for himself. This mode of procedure enables a man to make a progressive effort to gain a job which is within reason and which will enable him to gain additional valuable experience. He has now reached the point of knowing what he wants, why he wants it, and why he should have it. A man in possession of these facts is a hard individual to turn down, and what is more important, he has acquired confidence.

Logically, the next step is to find a market for the goods. This is where the Bureau, advertisements, letters, and personal tips should be used. Bear in mind these are media only, and none of them will or can get the job itself, they merely place one in touch with it. Most jobs, and particularly the good ones, are "By Letter", so it behooves the applicant to give heed to what constitutes a successful letter.

Avoid wasting a paragraph or even a sentence telling how the job was located—the heading does that. Set forth the qualifications in general, but forceful, terms—the experience record will give the details and proof. Above all, be concise, for if you really know you will fill the job, your letter will show it. No man, not a genius, can dash off an effective letter in an hour. A successful letter is well worth several hours of effort. Even after composing what appears to be a good letter, its value must be tested in the open market—and the first attempt is rarely successful. Persistence plus knowledge and confidence must inevitably win.

Finally comes the interview. Its success will be dependent on the personal impression, an intelligent expression of requirements and qualifications, and mutually satisfactory terms. Physical appearance counts for a great deal.

Some are naturally gifted, others are not. One's natural inclinations usually tend toward work with which his physical appearance accords. One does not pick a dray horse for the race track. Therefore, look to the neatness of clothes, face, and shoes and let the guest beware of his manners. Watch carefully the questions and answers, as the tongue has often slipped many a man out of a good job. Lastly, endeavor to be reasonable in one's demands, for if the employer does not use good business judgment in dealing with the employee, the latter will not long have a job. The following summary will probably be more effective than the foregoing remarks. In any event, it is hoped that either or both will make a few of the job hunters think.

Hints on Job Getting

1.—Decide on what you want.

2.—Make sure your qualifications give you an even chance of getting it. Do not think 100% is necessary. Perfection does not exist.

3.—Do not go after a job unless you mean business.

4.—There are three factors to every job, *viz.,* advancement, experience, salary. Do not ignore the first two.

5.—Remember that the job gets the salary, not the applicant's qualifications.

6.—Job getting is selling one's services. The successful salesman knows his product thoroughly. Study your goods.

Letter Writing

1.—The object of a letter is to get an interview. Letters do not get jobs.

2.—Padding of payrolls is a felony. Padding of letters is equally dangerous for the job hunter.

3.—A letter must: Arouse interest; create desire; prove the case; and convince the reader that an interview will be profitable. Therefore: Be as brief as is consistent to prove your claims. Make no claims not backed by the experience record. Always include the experience record.

4.—Attractive packages improve the sale of goods. Therefore, typewritten letters on plain business stationery are better than long-hand letters on club or personal stationery.

Interviews

The interview is "the day in Court". Getting it is only one-half the battle. When being interviewed:

1.—Be confident of your worth, but not presumptious.

2.—Be sure you want the job and be ready to prove why you should get it.

3.—Ask a fair market price for your goods. Do not profiteer. Do not be a philanthropist.

4.—Assay the three elements: Advancement, Training, Salary, and be guided by the sum of the three in accepting or declining.

5.—Leave in a pleasant, hopeful manner if the job is not decided then and there.

6.—A letter of acknowledgment of the courtesy of an interview is good policy following a promising call.

Finally, maintain the proper mental attitude. Do not let your morale slump. No one wants a grouch or a man who is not sure of himself.

Report of
Standing Committee of the Vitrified Paving Brick Conference

On November 15th, 1921, the general Conference on Paving Brick eliminated fifty-five out of the sixty-six varieties of paving brick,* and at the same time appointed a Standing Committee to consider further elimination in this field. This Standing Committee met on March 27th, 1922, and eliminated four additional types, leaving the following as recognized sizes and varieties of paving brick:

Variety.	Width, in inches.	Depth, in inches.	Length, in inches.
Plain wire-cut brick (vertical fiber lugless)	3	4	8½
	3½	4	8½
Repressed lug brick	3½	4	8½
Wire-cut lug brick (Dunn)	3½	3	8½
	3½	3½	8½
	3½	4	8½
Hillside lug brick (repressed)	3½	4	8½

Appointment of
Former Enlisted Men as Officers of the Reserve Corps

It is well known that, during the early months of this country's participation in the World War, engineers and others of education, ability, and experience, waived the opportunity of obtaining commissions and enlisted in the Engineer Regiments that were being recruited for immediate service in France. Thus, it happened that in many of these regiments, a large proportion of the rank and file were graduates of colleges or technical schools, with all the qualifications requisite for Engineer Officers.

In the event of a future emergency, such men, by reason of their professional accomplishments, combined with their military experience, would be of inestimable value as Engineer Officers. Although it is true that even though these men may not now enroll in the Reserve Corps, they would come forward in time of need, and their value would be greatly enhanced should they accept commissions now, for by this means they would keep in touch with military developments.

The present project for six volunteer field armies for the National Defense calls for an ultimate strength of 9 000 Engineer Officers. The present total, including Regular Army, National Guard, and Organized Reserve, is less than 4 000. It is the policy of the War Department to enroll in the Engineer Section of the Officers' Reserve Corps those who served as enlisted men during the World War, provided they have the technical qualifications to warrant such appointment. They will be appointed in grades commensurate with their positions and responsibilities in civil life. Men of this type can be enrolled in the higher grades without affecting in any degree the appointment as Second Lieutenants of the young and inexperienced graduates of the Reserve Officers' Training Corps units of the Universities.

* *Proceedings,* Am. Soc. C. E., December, 1921, p. 950.

In considering applications of enlisted men for commissions in the Engineer Reserve Corps, examining boards will exercise a wide discretion and will give great weight to professional and technical ability rather than a detailed knowledge of military regulations. Candidates for appointment will be expected to demonstrate by their past achievements and present worth that they have the capacity to adapt themselves to the military system should occasion arise, but they will not be rejected because of present unfamiliarity with military subjects alone. Officers so appointed will be given an opportunity to receive the necessary instruction in military subjects before they are called on for actual service in their grades or before they are eligible for promotion to the next higher grade.

Detailed information may be had by writing to the Chief of Engineers, Washington, D. C., or to the Corps Engineer at the headquarters of any of the nine Corps Areas into which the country is divided.

ACTIVITIES OF LOCAL SECTIONS*

Meeting of Buffalo Section

A meeting of the Buffalo Section was held on April 4th, 1922, at the Old Colony Club, Buffalo, N. Y.; President A. L. Johnson in the chair; and Bruce L. Cushing, Secretary.

The address of the evening was made by Dr. Julian Park, Dean of the University of Buffalo, whose subject was "Education". In the course of his address, Dr. Park paid particular attention to the past, present, and future subjects taught in the University of Buffalo. He outlined the growth of the University since its organization in 1846, stating that the first engineering classes were started in 1921 and asking the co-operation and assistance of local engineers in this work.

The following officers of the Section were elected for the ensuing year: President, Walter McCulloh; Vice-President, Elwin G. Speyer; and Secretary-Treasurer, John H. Feigel.

Meetings of Cleveland Section

A meeting of the Cleveland Section was held at the Hotel Winton on February 8th, 1922; President A. V. Ruggles in the chair; George H. Tinker, Secretary; and present, also, 15 members.

The address of the evening was made by Professor Sherman, of the Ohio State University, who discussed the "Proposed Cross-State Canal".

Meeting of February 22d, 1922

A called meeting of the Section was held at the Hotel Winton on February 22d, 1922, to meet Acting Secretary Elbert M. Chandler of the Society; President A. V. Ruggles presided at the meeting; George H. Tinker, Secretary.

Acting Secretary Chandler addressed the meeting on the April meeting of the Society to be held in Dayton, Ohio, and also on the Society Budget for 1922.

On motion, duly seconded, the Secretary was directed to arrange a conference with representatives of the other Ohio Sections during the meeting at Dayton.

Meeting of March 8th, 1922

A meeting of the Section was called to order at the Hotel Winton on March 8th, 1922; President A. V. Ruggles in the chair; George H. Tinker, Secretary; and present, also, 42 members and guests.

The minutes of the meetings of February 8th and February 22d, 1922, were read and approved.

The Secretary presented several communications from Acting Secretary Elbert M. Chandler.

On motion, duly seconded, a letter-ballot of the Section was ordered taken on the question of the advisability of the Society joining the Federated American Engineering Societies.

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* For list of Local Sections, Officers, etc., see p. 430.

The question of the advisability of publishing sections of the catalog of the Engineering Societies Library in *Proceedings,* was discussed, and it was the consensus of opinion that such publication would be a useless expense.

After announcements in regard to the Society meeting at Dayton, Ohio, the meeting was addressed by Mr. W. H. Dittoe, Chief Engineer, State Board of Health, on the "Pollution of Lake Erie." This paper was followed by a general discussion by those present.

Meeting of April 12th, 1922

A meeting of the Section was held at the Hotel Winton on April 12th, 1922; Past-President J. E. A. Moore in the chair; George H. Tinker, Secretary; and present, also, 10 members.

The minutes of the meeting of March 8th, 1922, were read and approved.

The Secretary presented a communication from the Acting President of the Carnegie Institute of Technology in reference to the Second Conference on Engineering Education, and on motion, duly seconded, the Secretary was instructed to find a delegate for this Conference.

A communication from Acting Secretary Chandler in reference to a set of *Transactions* of the Society, and the appointment of a representative of the Section on the Sub-Committee on Power of the Committee on Publications, was presented. On motion, duly seconded, it was decided that the Section would not ask for a set of *Transactions,* and Mr. J. H. Tufel was recommended to represent the Section on the Sub-Committee on Power.

The Secretary reported the result of the Conference of Section Delegates at the Dayton meeting of the Society on April 6th, 1922.

On motion, duly seconded, it was decided that the order of business for the May meeting of the Section should be the Report of the River and Harbor Committee.

Meeting of Colorado Section

The 123d regular meeting of the Colorado Section was held at the Metropole Hotel, Denver, Colo., on March 27th, 1922; President A. N. Miller in the chair; Thomas H. Olds, Secretary; and present, also, 10 members and 2 guests.

The minutes of the previous meeting were read and approved.

The Secretary announced the resignation of Mr. H. L. Thackwell as a member of the Section, which, on motion, duly seconded, was accepted.

Relative to the grouping of the membership of the Society in District No. 11 by which a large proportion of the membership of the District is in the extreme southwest corner of the area, on motion, duly seconded, a resolution* was adopted, protesting against this grouping, and the Secretary was instructed to mail a copy of this resolution to the Society.

Mr. Julian Hinds, of the U. S. Reclamation Service, addressed the meeting on the subject "Some Experiences in the Operation of High-Pressure Reservoir Outlets". He described the installations for the Roosevelt, Path-

* See p. 385.

finder, Shoshone, and Strawberry Valley Dams, the difficulties in their operation, and the steps taken to remedy the defects.

Meetings of Connecticut Section

A meeting of the Connecticut Section was held at the Hotel Bond, Hartford, Conn., on March 7th, 1922; President W. J. Backes in the chair; C. M. Blair, Secretary; and present, also, 14 members.

On motion, duly seconded, it was decided to accept the invitation of the Hartford Branch of the Connecticut Section of the Mechanical Engineers to a joint meeting at Hartford on April 11th, 1922.

The subject "Traffic and Transportation Problems" was considered and discussed.

Meeting of March 25th, 1922

A meeting of the Connecticut Section was called to order at the Graduates' Club, New Haven, Conn., on March 25th, 1922; President W. J. Backes in the chair; C. M. Blair, Secretary; and present, also, 22 members and 2 guests.

The purpose of the meeting was to consider and take action on the matter of the Society joining the Federated American Engineering Societies. Professor C. F. Scott, of Yale University, and a Director of the Federated American Engineering Societies, who was present as a guest, addressed the meeting and explained the purposes and activities of the Federation. Director F. E. Winsor, who was also a guest at the meeting, presented reasons for and against joining the Federation.

A motion that "it is the sense of the Connecticut Section of the American Society of Civil Engineers that the American Society of Civil Engineers should join the Federated American Engineering Societies", was made and duly seconded. An amendment to the effect that the date of joining should be at the end of the present fiscal year of the Society, was offered and incorporated in the original motion. The vote on this motion resulted in 7 for and 15 against the resolution.

A report was presented by the delegates to a preliminary conference in regard to a proposed affiliation of the Engineering Societies of Connecticut, recommending that the Section should not join this affiliation. On motion, duly seconded, the report of the delegates was accepted and the recommendation adopted.

Meeting of Duluth Section

A meeting of the Duluth Section was held on April 17th, 1922; President John L. Pickles in the chair; Walter G. Zimmermann, Secretary; and present, also, 21 members and 1 guest.

The President introduced the guest of the evening, Mr. R. W. Acton, Engineer of Roads for St. Louis County, Minn.

The minutes of the meeting of the Section of March 20th, 1922, were read and approved.

The Secretary presented a letter from Acting Secretary Chandler asking the Section to suggest a member to act as representative on the proposed Sub-Committee on Power of the Committee on Publications. The Board of

Directors of the Section presented the name of Mr. Francis A. Cokefair, and the Secretary was instructed to advise Mr. Chandler of that fact.

The meeting having been turned over to the Entertainment Committee, the Chairman of that Committee, Mr. O. H. Dickerson, presented Maj. E. H. Marks, who spoke on "The Standardization of Map Scales". The subject was discussed by those present, but as it was too large to be concluded at this meeting, a motion was made, seconded, and carried, that a committee be appointed to study the subject and bring in a report with recommendations at the next meeting of the Section. President Pickles subsequently appointed Maj. Marks, Chairman, and Messrs. Christie, Darling, Hutchinson, Lawrie, and Reed as such Committee.

President Pickles called attention to the fact that the next meeting would be the Annual Meeting of the Section for the election of officers and requested that the members make it a point to be present and suggest the names of members for officers for the next year.

President Pickles stated that, at the present time, the Section consists of 36 active members (32 resident in Duluth and 4 non-resident members), that three applications have been sent in to Society Headquarters, and that there were five other prospective members who are considering making applications for membership.

Meetings of Los Angeles Section

The meeting of the Los Angeles Section was held on February 8th, 1922, at the City Club; President Ralph J. Reed in the chair; F. G. Dessery, Secretary; and present, also, 38 members and 10 guests.

President Reed introduced the speaker of the evening, Mr. Franklin D. Howell, Consulting Engineer and General Manager of the Motor Transit Company, who addressed the meeting on "Motor Stage Transportation and Some of the Problems Encountered in the Operation Thereof". The subject was discussed by Messrs. Dennis, La Rue, Hill, Wheeler, Bennett, Thomas, Code, Reed, Barnard, Bowen, Cory, Rowe, Comber, and Anderson. At the conclusion of the discussion, President Reed, on behalf of the Section, thanked Mr. Howell for his instructive address.

On motion, duly seconded, the minutes of the previous meeting were approved as written.

The election of Messrs. F. W. Blackford, H. T. Cory, C. Robert Adams, and O. A. Stone as members of the Section was announced. President Reed announced the resignations of Messrs. Ward Hall, H. A. Larsen, and L. R. Walker as members of the Section.

A letter of February 6th, 1922, from W. T. Knowlton, Engineer of Sewers, in which he pointed out the urgency of a permanent sewage disposal system for Los Angeles, was referred to the Sewer Committee with instructions to consult with the City Engineer if necessary.

Director George G. Anderson presented a brief résumé of the January meeting of the Board of Direction of the Society. He favored the Society joining the Federated American Engineering Societies, the recataloging of the Engineering Societies Library, and the proposed amendments to the Constitution.

On motion, duly seconded, it was unanimously decided that it was the sense of the meeting that the Society become a member of the Federated American Engineering Societies.

A motion to the effect that additional sections of the catalog of the Engineering Societies Library be published in *Proceedings* from time to time, having been duly seconded, was adopted.

President Reed announced the death of Karl D. Schwendener, M. Am. Soc. C. E., a member of the Section, and appointed Messrs. J. E. Rockhold and Blaine Noice to prepare resolutions and a memoir.

Meeting of March 8th, 1922.

A meeting of the Los Angeles Section was held on March 8th, 1922, at the City Club; President Ralph J. Reed in the chair; F. G. Dessery, Secretary; and present, also, 40 members and 16 guests.

President Reed announced the death of Edgar True Wheeler, M. Am. Soc. C. E., on March 2d, 1922, and on motion, duly seconded, appointed Messrs. F. G. Dessery, H. Hawgood, and P. B. Harris as a committee to draft resolutions on the death of Capt. Wheeler.

The subject for discussion at the meeting, "The Conservation of the Water Resources of California", was announced by President Reed who also introduced the guests of the Section, J. C. Forkner, Chairman of the Consulting Board of the State Water Commission, and Messrs. Bailey, Etcheverry, Marshall, McGlashan, and Attorney-General U. S. Webb of California, all members of the Consulting Board, and Mr. F. C. Scobey, Engineer in Charge of Water Investigations.

During the discussion which followed, Chairman Forkner read the Legislative Act authorizing the appropriation for the study of water resources of the State and the formation of the Consulting Board. He was followed by Deputy State Engineer Bailey, who presented an outline of the accomplishments to date in the collection of data. A general discussion of the subject was then participated in by Messrs. Hill, Lippincott, Mulholland, Howell, Anderson, Morris, and Sonderegger, and also by City Attorney Jess E. Stephens as representative of the Bar Association, and Attorney-General Webb, both of whom discussed the legal phases of water conservation.

Mr. F. L. Sellew, Chairman of the Standing Committee on Sewerage, presented the report of this Committee, to which the communication of Mr. W. T. Knowlton regarding the sewerage situation of Los Angeles had been referred. The report was generally discussed and on motion, duly seconded, was approved and adopted. The Board of Directors, as a Committee, was instructed, on motion, duly seconded, to prepare and present to the City Council, Municipal League, Realty Board, Chamber of Commerce, and other interested parties, a summary of this report.

Meeting of April 12th, 1922

A meeting of the Los Angeles Section was held at the City Club on April 12th, 1922; President Ralph J. Reed in the chair; F. G. Dessery, Secretary; and present, also, 61 members and 36 guests.

A letter was presented from Director George G. Anderson in regard to the Dayton meeting of the Society.

President Reed announced that the 1922 Roster and Constitution of the Section would soon be ready for distribution.

A communication from the American Association of Engineers, inviting the Section to attend the meeting of that Association, was read by President Reed. This meeting is to be addressed by Professor Duff Abrams, M. Am. Soc. C. E., relative to the work he is doing on concrete at the Lewis Institute, Chicago, Ill.

Resolutions on the deaths of Karl DeWitt Schwendener, M. Am. Soc. C. E., and Edgar True Wheeler, M. Am. Soc. C. E., members of the Section, were, on motion, duly seconded, adopted.

President Reed introduced City Engineer J. A. Griffin, who spoke in detail on "The City's Serious Sewerage Situation". In the course of his remarks, Mr. Griffin outlined the various temporary methods proposed to handle the situation until permanent relief has been secured. The subject was discussed by Messrs. W. T. Knowlton, Engineer of Sewers, Barnard, Rowe, Hill, Sawyer, and Olmsted. President Ralph Criswell, of the City Council, spoke on the attitude of the City Council in the matter, and the subject was further discussed by Messrs. Binckley, Sellew, and Lippincott.

After his discussion, Mr. Lippincott made a motion to reconsider the report of the Standing Committee on Sewerage which was adopted by the Section at its meeting of March 8th, 1922. After discussion by Messrs. Hawgood, Jubb, Knowlton, Griffin, Smith, Lippincott, Trask, Binckley, Criswell, Sellew, Dennis, Patch and Kerr, President Reed called for a vote on the motion for a reconsideration of the report of the Committee on Sewerage, which motion was duly carried.

On motion, duly seconded, the Section, on reconsideration of this report, adopted the report in full with the exception of the Committee's suggestion that pumps be installed in the outfall sewer.

The following resolution was, on motion, duly seconded, adopted:

"This Section realizing the urgency of the entire sewerage situation and lack of understanding by the citizens of Los Angeles authorize the President to appoint a committee of seven, to be known as a 'Committee on Publicity', to aid the campaign in favor of an outfall sewer."

President Reed subsequently appointed Messrs. Sellew, Adams, Barnard, Bowen, Howell, Olmsted, and Dessery as such Committee.

Meeting of Louisiana Section

A regular meeting of the Louisiana Section was held on April 12th, 1922, at the residence of the President in New Orleans, La.; President Ole K. Olsen in the chair; F. A. Muth, Secretary; and present, also, 16 members and guests.

The minutes of the previous meeting were read and approved.

The following officers were elected for the ensuing year: President, Donald Derickson; and Second Vice-President, Samuel M. Young. The following

officers are hold-overs, their term of office being for two years: First Vice-President, E. H. Coleman; Treasurer, C. N. Bott; and Secretary, F. A. Muth.

The meeting was followed by a delightful supper and smoker.

New York Section in Joint Meeting on Muscle Shoals Project

The fourth Joint Meeting of the Metropolitan Sections of the four Founder Societies was held in the Auditorium of the Engineering Societies Building on April 14th, 1922, with W. S. Finlay, Jr., Chairman of the Metropolitan Section, American Society of Mechanical Engineers, in the chair, and about 800 members and guests present. The programme had been arranged by the Ordnance Division of the American Society of Mechanical Engineers on the subject, "Muscle Shoals as a Power and Nitrates Producer", to be presented in two phases: First, from the standpoint of power production; and, second, from that of nitrates production both for commercial and munitions purposes.

Before the speakers on the main phases of the topic were introduced, the Chairman presented Mr. Theodore Nagel, Consulting Engineer, who explained the chemical processes in the production of ammonium nitrate, and moving pictures showing the various details of the Muscle Shoals plant were exhibited.

Brig.-Gen. Harry Taylor, Assistant Chief of Engineers, U. S. A., discussed the project as a power producer, illustrating his address by lantern slides. Mr. W. S. Landis, Chief Technologist of the American Cyanamid Company, discussed the commercial uses of the plant, and Maj.-Gen. C. C. Williams, Chief of Ordnance, U. S. A., presented the general subject of fixed nitrogen as a raw material of war, and its importance in the manufacture of munitions, and included a description of various Government nitrate plants. Mr. F. E. Frothingham, of Coffin and Burr, Bankers, presented the bankers' point of view, and compared the offers made by the Alabama Power Company and by Mr. Henry Ford. Mr. E. A. Yates, of Wood, Hulse and Yates Company, Engineers, made a plea to have the power distributed to the adjoining territory for general industrial purposes.

Nominating Committee Elected at Business Meeting

At a regular business meeting of the New York Section held at 7:30 P. M., preceding the Joint Meeting, President Nelson P. Lewis in the chair, J. P. J. Williams, Secretary, and about 25 members present, the following were unanimously elected to serve on the Nominating Committee to present the names of officers to be elected at the Annual Meeting of the Section in May; Messrs. J. B. French, George L. Lucas, James H. Edwards, Clifford Holland, and Thaddeus Merriman.

A letter was read inviting the Section to appoint one representative to serve on the Committee on City Departments, which is composed of delegates from the New York Chapter of the American Institute of Architects, the Building Trades Employers Association, the New York Board of Fire Underwriters, the American Institute of Consulting Engineers, the Brooklyn Chapter of the American Institute of Architects, the New York Society of Architects, and the Iron League of New York. After parts of the Constitution under which the Committee functions, were considered, it was moved, seconded, and carried, that the invitation be referred to the Board of Directors, with power.

Second Sub-Section Conference on Design

At 5:15 P. M., preceding the foregoing meetings, the second of the series of three Sub-Section Conferences was held, Mr. James H. Edwards, Assistant Chief Engineer of the American Bridge Company, presiding, and about 35 members present. The subject "Structural Design and Details—the Responsibility of the Engineer" was discussed with general interest, resulting in a motion, duly seconded and carried, directing the Chairman to appoint a committee of three, including himself, to present to the next meeting of the Sub-Section a form of resolution suitable to bring before the Section to obtain action toward a revision of laws or building codes of the United States, in order to provide more effective safeguards to the public in the methods of control over the design and construction of places of public assembly. The Chairman subsequently appointed Messrs. J. B. French and Eugene W. Stern to serve with him on this Committee.

Joint Meeting of the Northeastern Section and Boston Society of Civil Engineers

A joint meeting of the Northeastern Section and the Boston Society of Civil Engineers was held on April 26th, 1922, in Gilbert Hall, Tremont Temple, Boston, Mass.; Chairman Frank B. Sanborn presiding; Charles W. Banks, Secretary; and present about 75 members of both Societies and guests.

The object of this meeting was to discuss "Universal Form of Contract", and this subject was presented by representatives of the engineering, architectural, and contracting professions, including Gen. William H. Rose, and Messrs. William Stanley Parker, Arthur W. Dean, J. Parker Snow, Frank M. Gunby, and Arthur C. Tozzer. The addresses were followed by discussion from the floor by Professors C. Frank Allen and Charles M. Spofford, and Messrs. Wason, Larned, Nelson, and others. The opinion of the majority of the speakers seemed to be that the "Universal Form of Contract" when it could be prepared acceptably to the different interests concerned, would be very desirable and would accomplish much.

Meeting of Northwestern Section

A meeting of the Northwestern Section was held at the Minneapolis Athletic Club, Minneapolis, Minn., on March 31st, 1922; President W. T. Walker in the chair; Bernard Blum, acting as Secretary; and present, also, 19 members.

After discussing local Society matters, President Walker called attention to the fact that dues had not been collected and the Minnesota Federation of Engineers was calling for the payment of the tax of Section members. On motion, duly seconded, the President and officers of the Section were authorized and requested to serve notices and collect dues and also the amount due to the Minnesota Federation.

President Walker left the meeting and Vice-President Herrold took the chair.

The report of Mr. P. E. Thair, delegate of the Section to the meeting of District No. 7, held in Chicago, Ill., on March 17th, 1922, was read, and on motion, duly seconded, the report was received and placed on file.

The question of the Society joining the Federated American Engineering Societies was discussed, and on motion, duly seconded, the meeting endorsed the plan of the Society joining the Federation, and the Secretary was instructed to request the Society to send out a letter-ballot on the question.

A motion that the Section express itself as in favor of holding a Zone Meeting annually was duly seconded and carried.

On motion, duly seconded, the Chairman was instructed to appoint a representative of the Section to attend the meeting of the Society at Dayton, Ohio, and report back to the Section. The Chairman subsequently appointed President Walker as such representative.

On motion, duly seconded, the Secretary was instructed to notify Mr. Anson Marston, Chairman of the Conference Committee of District No. 7, of the action taken by the meeting on the recommendations of the meeting in Chicago on March 17th, 1922.

On motion, duly seconded, the Chairman was authorized to appoint a committee of three to investigate the question of a paid Secretary for the Section and report back at the next meeting. Mr. Herrold subsequently appointed Messrs. Clements, Wilson, and Hutchinson as such Committee.

Meetings of Philadelphia Section

A joint meeting of the Philadelphia Section was held at the Engineers' Club on March 6th, 1922, with the Engineers' Club, the Society of Municipal Engineers, and several National Engineering Societies; President Benjamin Franklin in the chair; Lewis R. Ferguson, Acting Secretary; and present, also, 120 members and guests.

The subject for discussion, "Zoning and Its Relation to City Development", was opened by Mr. Lawson Purdy, of New York City, who described the development of zoning in New York City and the benefits derived from its application. Mr. Purdy was followed by Mr. B. A. Haldeman, of the Pennsylvania State Bureau of Municipalities, who discussed the subject from the standpoint of its value in promoting orderly growth. Mr. M. B. Medary, Jr., a member of the Philadelphia Zoning Commission, discussed the general features of the zoning ordinance now being prepared for that city, illustrating his remarks with lantern slides.

Meeting of March 21st, 1922

The Philadelphia Section participated in a symposium on Hydro-Electric Development which was held on March 21st, 1922, by the Engineers' Club of Philadelphia and other Sections of the National Engineering Societies.

The Section was represented at these meetings by N. C. Grover, Chief Hydraulic Engineer of the U. S. Geological Survey, who discussed the subject "The Relations of Water Resources to the Country's Development".

Meeting of April 3d, 1922

A regular meeting of the Section was held at the Engineers' Club on April 3d, 1922; President Benjamin Franklin in the chair; Lewis R. Ferguson, Acting Secretary; and present, also, 43 members and guests.

On motion, duly seconded, the proposed revision of the Constitution and By-Laws of the Section was approved and ordered sent to letter-ballot.

On motion, duly seconded, a resolution was adopted unanimously re-affirming the former position of the Section that the Society should join the Federated American Engineering Societies as soon as its finances permit.

The meeting was devoted to an explanation of the work of the Committee of the Engineers' Club in evaluating the desirability of the several sites proposed for the Sesqui-Centennial in 1926, which was done at the request of the Executive Committee of the Sesqui-Centennial Association. Mr. W. P. Parker, who was Chairman of the Co-ordinating Committee, described the basis on which the evaluation was made, and his explanation was supplemented by remarks by Mr. J. A. Vogleson and others.

Meeting of May 1st, 1922

A meeting of the Philadelphia Section was held on May 1st, 1922; President Benjamin Franklin in the chair; Lewis R. Ferguson, Acting Secretary; and present, also, 135 members and guests.

After a short business session, the meeting was addressed by John R. Freeman, President, Am. Soc. C. E., on "Some Engineering and Industrial Problems in China and the Far East", the address being illustrated with lantern slides.

Preceding the meeting, a dinner was given by the Section in honor of President Freeman, which was attended by many of the most eminent engineers of the city.

Activities of San Diego Section

On January 28th, 1922, members of the Section were invited to inspect the works under construction by the U. S. Navy Department in San Diego. Among the various units inspected were the Naval Training Station and Marine Barracks, the former being under construction and the latter recently completed, the hospital in Balboa Park, which is nearing completion, and the Repair Base on the site of the former concrete shipyard of the Emergency Fleet Corporation. The party was conducted by Lieut. H. G. Lehrbach, of the Naval Public Works Office, who described the principal features of the works visited.

The program for the meeting on February 21st, 1922, was a discussion of the Progress Report of the Joint Committee on Tentative Specifications for Concrete and Reinforced Concrete. The discussion was opened by Messrs. J. T. Vawter and R. W. Whitaker, and was participated in by the members present.

Through the courtesy of Mr. H. N. Savage, Hydraulic Engineer of the City of San Diego, the members of the Section were invited to visit Barrett

Dam on March 12th, 1922. Those taking the trip were guests of Mr. Savage at a dinner which was followed by an inspection of the work on this structure now nearing completion.

The meeting of the Section of March 18th, 1922, was a dinner meeting, with Director George G. Anderson as the guest of honor. The business meeting which followed, was devoted to discussion of Society matters of general interest to the Local Sections, regarding which Mr. Anderson furnished much information to the members present.

Mr. F. J. Grumm has tendered his resignation as President of the Section, on account of his removal to Sacramento, Calif., and the office has been filled by the appointment thereto of Mr. P. R. Watson, Vice-President of the Section.

Meeting of San Francisco Section

A regular meeting of the San Francisco Section was held at the Engineers' Club on February 20th, 1922; President Thomas H. Means in the chair; Henry D. Dewell, Secretary; and present, also, 86 members and guests.

President Means announced that the Section had been honored by having two of its members awarded prizes by the Society for papers presented during the year, and that Messrs. Fred A. Noetzli who had received the J. James R. Croes Medal, and L. Standish Hall who had been awarded the Collingwood Prize, were the guests of the Section at the meeting.

The Secretary announced the appointment, by President Means, of members of the Excursion Committee, the Publicity Committee, and the Committee on Society Welfare for 1922.

Director W. L. Huber and Vice-President C. E. Grunsky reported on the proceedings of the Annual Meeting of the Society in New York City. It was announced in this report that the Board of Direction had adopted the plan of holding professional meetings in the Spring and Fall in different parts of the country, the first meeting to be held in Dayton, Ohio, in April, and the second in San Francisco in October, 1922.

Mr. E. T. Thurston addressed the meeting on the work of the Joint Conference of Engineers, Architects, and Constructors which was held in Washington, D. C., in December, 1921, for the purpose of producing a standard form of contract agreement for all sections of the United States and for all phases of industry. It was suggested that as the laws and customs of different sections of the country might require special consideration with regard to contract forms, that the various points of view might be obtained through the Local Sections. On motion, duly seconded, a resolution was adopted embodying this suggestion, and the Secretary was instructed to request the Society to supply all Local Sections with a complete draft of the proposed contract form and to invite comment thereon.

A letter was presented from Acting Secretary Chandler relative to the allocation to Local Sections of a part of the dues of their members, and it was stated that the Secretary had forwarded a membership list of the Section, showing 232 members to the Headquarters of the Society.

The Secretary presented a letter from Acting Secretary Chandler relative to the resolution passed by the Board of Direction directing him to communicate with all Local Sections that the Board would, at its April meeting, consider the question of the Society becoming a member of the Federated American Engineering Societies, and to ascertain the sentiment of the members of the Section on the subject.

In this connection a letter was presented by the Secretary from Past-President Muhs urging that the Section decline to join the Federation on account of financial and other reasons. Mr. W. L. Huber also read a personal letter from Mr. Robert Ridgway of New York City, who advanced the same arguments made by Mr. Muhs and who also reported that a meeting of the New York Section had voted unfavorably on this matter. Mr. Grunsky spoke in favor of the Society joining the Federation and moved that a post-card vote of the Section be taken on the subject, which motion was seconded. After amendments to this motion had been made and carried, and the subject had been discussed by Messrs. Muhs, Rhodin, Thurston, Tibbetts, and Galloway, a vote on the original motion resulted in a tie.

It was then moved and seconded that the meeting vote on whether or not it was in favor of a National organization of engineering societies. After some discussion, it was decided, by rising vote, that the meeting was not in favor of a National organization of engineering societies.

The subject of the meeting was presented by Mr. William Cushing Edes, who presented "A Little Talk on Alaska by a Civilian Engineer Engaged in Government Work". In the course of his address, Mr. Edes presented briefly a history of the Government railroad work in Alaska under the Alaskan Engineering Commission, and illustrated his remarks with slides showing typical Alaskan scenery, agricultural, and natural products, and scenes of construction along the railroad.

Excursion to Sacramento

On March 24th, 1922, twenty-four members of the Section left on the boat of the California Transportation Company for Sacramento, Calif., where they were met by representatives of the City and by the Sacramento members of the Society, and transported by automobiles to the City Pumping Plant and, later, to the yard of the Valley Pipe Company. The party made a tour of inspection of the Pumping Plant, under the direction of Professor C. G. Hyde and his associates, and the work being done there was explained by model and plans. Photographs showing the progress of the work since the beginning were also exhibited.

The yard of the Valley Pipe Company was next visited where the party was invited to witness tests of concrete pipe. These tests consisted of breaking concrete sewer culvert pipe of different diameters and different thicknesses, both reinforced and unreinforced. There were also tests by water pressure applied to the interior and exterior of the pipes. The pipe tests were witnessed by about 45 members.

After luncheon at the Hotel Land in Sacramento, the party attended the ceremony in connection with the commencement of work on the new State Building.

Meetings of Seattle Section

A meeting of the Seattle Section was held at the Engineers' Club on March 27th, 1922, at 8 P. M.; President F. F. Sinks in the chair; Frank H. Fowler, Secretary; and present, also, 30 members.

The minutes of the previous meeting were read and approved.

The revised Constitution of the Society relative to the election of officers was outlined by Mr. Joseph Jacobs.

Messrs. A. S. Downey and S. H. Hedges reported on the Association of General Contractors of America and explained its activities.

Mr. T. E. Phipps, for the Legislative Committee, reported on the discussion at the meeting of the Advisory Committee in regard to the activities of the Committee.

The work of the Membership Committee was discussed by Mr. T. R. Beeman.

A suggestion by Mr. Phipps that members from out of town be asked to pay only a nominal amount of dues was referred to the Membership Committee.

The three-cent fare bill was discussed by Mr. Shields, and the subject of taxation and utilities was discussed by Messrs. Dimock, Hedges, Holmes, Hall, and Phipps. During this discussion, the suggestion was made that the Section investigate the basis of taxation in Seattle and other coast cities, and the duty of members of the Society in relation to the consideration of public questions was also discussed.

A motion that the Section at its March meeting discuss and declare itself unanimously against the Erickson Bill was referred to the Legislative Committee.

Mr. Harding, Secretary of the General Contractors' Association, addressed the meeting on the objects and aims of that organization.

Meeting of April 24th, 1922

A regular meeting of the Seattle Section was held at the Engineers' Club on April 24th, 1922; President F. F. Sinks in the chair; Frank E. Fowler, Secretary; and present, also, 15 members.

The minutes of the meeting of March 27th, 1922, were read and approved.

A letter from William G. Atwood, M. Am. Soc. C. E., Director, Marine Piling Investigations, of the National Research Council, outlining a proposed marine piling investigation to be held in Seattle, was referred to Mr. R. J. Middleton and his committee for report and suggestions.

A letter from the San Francisco Section requesting the co-operation of the Section in the matter of the Fall meeting of the Society to be held in San Francisco, was referred to the Entertainment Committee for action.

The Secretary presented a letter from Acting Secretary Chandler requesting advice regarding the shipment of volumes of *Transactions* to the Section. On motion, duly seconded, the Secretary was instructed to advise Mr. Chandler to ship the available volumes unbound.

The Report of the Parent Relationship Committee regarding the advisability of the Society joining the Federated American Engineering Societies was read, and approved, and on motion, duly seconded, the Secretary was instructed to transmit copies of the report to the Society and to the Duluth Section. In this report, the Committee favored the Society joining the Federated American Engineering Societies as soon as its financial condition would permit.

Mr. T. E. Phipps presented a report on the bill which is to come up at the May election of the City of Seattle regarding the abolishment of the Department of Public Utilities. The subject was discussed at length, and on motion, duly seconded, it was resolved that the Section disapprove of the abolishment of the Department of Public Utilities and of the creation of a Department of Transportation.

Maj. C. H. Reeves discussed in detail the workings of the Department of Public Utilities, and on motion, duly seconded, the publicity to be given the action taken by the Section on this matter and on the Section's decision on the so-called three-cent car fare bill was referred to the Legislative Committee for immediate action.

The address of the evening was presented by Maj. Jesse A. Jackson on "Some Aspects of City Zoning Applied to Seattle", and illustrated by maps and slides. At the conclusion of the address, a vote of thanks was tendered Maj. Jackson.

Special Meeting of Spokane Section

A special meeting of the Spokane Section was held on March 30th, 1922, at the East Banquet Annex, Davenport's; President C. A. Burnette in the chair; Charles E. Davis, Secretary; and present, also, 12 members.

A communication from the Seattle Section regarding territorial boundaries of the Seattle and Spokane Sections was read, the 120th Meridian being suggested as such boundary. The Columbia River and the west line of Okanogan County were suggested by the Section as being the more natural boundary line.

Annual Meeting of Utah Section

The Annual Meeting of the Utah Section was held at the University Club, Salt Lake City, Utah, on April 5th, 1922; President W. R. Armstrong in the chair; H. S. Kleinschmidt, Secretary; and present, also, 21 members and 4 guests.

The report of the Secretary-Treasurer was read, and on motion, duly seconded, accepted.

The following officers for 1922 were elected: President, B. W. Matteson; Vice-President, H. L. Baldwin; and Secretary-Treasurer, H. S. Kleinschmidt.

The Secretary presented a communication from the Society relative to volumes of *Transactions* available for Local Sections. As the Section has no permanent quarters, Mr. C. E. Painter offered to provide room for such *Transactions,* and on motion, duly seconded, his offer was accepted and the Secretary was directed to send for the volumes.

A letter from the Acting Secretary of the Society relative to the Sub-Committee on Power of the Committee on Publications, asking for suggestion as to a member from the Section for this Sub-Committee, was read. On motion, duly seconded, the President was authorized to make such appointment.

The meeting then adjourned to Barratt Hall, where a public meeting was held on "Reclamation", the attendance at which was about 400. The discussion was opened by Mr. E. C. LaRue, Hydraulic Engineer of the U. S. Geological Survey, who gave an interesting talk on the Colorado River, illustrating his remarks with colored lantern slides. He presented data as to available reservoir sites on that river and its tributaries, and as this subject is of interest to the people of Utah and adjoining States, a general discussion followed which was led by Mr. R. E. Caldwell, State Engineer.

The past, present, and prospective development of the Snake River in Idaho was discussed by Mr. F. A. Banks, Engineer of the U. S. Reclamation Service, at American Falls, Idaho, who also illustrated his talk with lantern slides.

Mr. William M. Greene, Engineer, U. S. Reclamation Service, at Salt Lake City, presented a brief address on the investigations now under way in Utah by the U. S. Reclamation Service, which is co-operating with the State of Utah through the Utah Water Storage Commission in this work.

President Matteson appointed Messrs. R. K. Brown and A. B. Villadsen as representatives of the Section on the Governing Board of the Utah Engineering Council, and Mr. LeR. M. Pharis as the member from the Section on the Sub-Committee on Power of the Committee on Publications of the Society.

EMPLOYMENT SERVICE OF THE FEDERATED AMERICAN ENGINEERING SOCIETIES

An Engineering Societies Service Bureau was established December 1st, 1918, as an activity of Engineering Council, managed by a board made up of the Secretaries of the four Founder Societies, funds for its maintenance being provided by these Societies. On January 1st, 1921, this Bureau was taken over by The Federated American Engineering Societies and is now known as the Employment Service of that organization. It is co-operating with engineering organizations in all parts of the country and is desirous of increasing such co-operation by working with local engineering associations and clubs. Members of the American Society of Civil Engineers who desire to register should apply for further information, registration forms, etc., to Walter V. Brown, Manager, Engineering Societies Building, 29 West 39th Street, New York City. In order to be included in the list published in *Proceedings,* copy must be received on or before the first Wednesday of each month. All communications should be addressed to Mr. Brown.

EMPLOYMENT BULLETIN

POSITIONS AVAILABLE

CIVIL ENGINEERS qualified to fill structural and architectural drafting positions will please apply at once to the Employment Service.

INSTRUCTORS: All engineers willing to consider teaching positions are invited to register with the Employment Service, which has been called on to fill positions varying in grade from laboratory assistant to heads of departments in various engineering and technical schools of the United States.

TWO COMPUTERS for sanitary work and for taking quantities from plans. Some designing will be required. Application by letter. Salary not stated. Location, New York City. V–901.

RESIDENT ENGINEER, energetic, live, and experienced for paper mill construction. Application by letter. Salary not stated. Location, Chicago, Ill. V–914.

THREE OR FOUR DRAFTSMEN familiar with general plant equipment, layout in connection with paper, pulp, and sulphite work. At least five years' experience. Salary in accordance with ability. Application by letter. Location, Chicago, Ill. V–915.

YOUNG CIVIL ENGINEER out of college about one year to do statistical work in office. Good future with a dependable firm. Application in person. Location, New York City. V–937.

TWO YOUNG CIVIL ENGINEERS for structural steel design on bridge work and inspection of existing bridges. Headquarters at Providence, R. I., and New Haven, Conn. Application by letter. V–974.

TWO YOUNG ENGINEERS to sell asbestos products of all kinds. Application in person. Salary not stated. Headquarters, New York City. V–995.

SALES ENGINEERS, chemical or mechanical. Several engineers to handle State territories on a liberal commission basis. Company manufactures an alloy combining unusual wearing qualities as a bearing metal, remarkable acid resistance, and great strength. Castings are made from 15 to 60 sclerescope, and from 75 000 to 100 000 lb. per sq. in. tensile strength. This metal has been on the market for eight years and is widely used by many nationally known concerns. An automobile valve, made of this alloy, is meeting with instant success wherever it has been introduced. The sales rights for this valve will be given along with other lines and will show a profit from the start. Application should state age, education, experience in detail, and choice of localities. A recent photograph is desirable. Headquarters, Wisconsin. V–1001.

SALES MANAGER for roofing department, to take care of office correspondence. Preferably one who knows New England territory and something of building construction and merchandising. Application in person. Salary not stated. Location, Boston, Mass. Headquarters, New York City. V–1007.

ENGINEER with thorough knowledge of passenger traffic routing on railroads. Application in person. Salary not stated. Location, New York City. V–1013.

BUILDING SUPERINTENDENT thoroughly experienced in building work, handling contractors, etc. Application by letter. Salary not stated. Location, Pennsylvania. V–1019.

DESIGNER AND DRAFTSMAN for structural steel building. Several months' work. Application by letter, stating experience and whether willing to go to Detroit. Salary not stated. Location, Detroit, Mich. V–1020.

SALESMEN to sell Ready Cut Homes direct from manufacturer. Men traveling in New England, West, and Middle Atlantic States.

May be used as side line. Liberal commission. Write for appointment. Location, Seattle, Wash. V–1021.

EXPERIENCED BRIDGE DESIGNER. Application by letter. Salary not stated. Location, Virginia. V–1023.

STRUCTURAL STEEL DRAFTSMAN, familiar with making shop details. Application in person. Age 25, four years' experience. Location, Newark, N. J. V–1030.

INSTRUCTOR, CIVIL ENGINEERING, to teach hydraulics, highway engineering, and surveying. Application by letter. Location, New York. V–1035.

ENGINEER to interview architects and prospective builders of houses, $20 000-$50 000 class, to secure contracts for same. Territory, Greater New York, and 50-mile radius. Must be A–1 and know business from bottom up. Application in person. Salary plus liberal commission. Headquarters, New York City. V–1043.

DESIGNER AND DRAFTSMAN with hydroelectric (dam) experience. Application by letter. Salary not stated. Location, New York City. V–1046.

GENERAL BUILDING ESTIMATOR AND OFFICE ASSISTANT for work in Japan. Must be thoroughly experienced with at least ten years' experience. Application in person. V–1052.

THREE OR FOUR FIRST-CLASS STRUCTURAL DETAILERS for apartment houses, theatres, etc. Application in person. Location, Long Island City, N. Y. V–1053.

STRUCTURAL STEEL DETAILERS AND CHECKERS, industrial plant building. Application by letter. Salary not stated. Location, Pennsylvania. V–1088.

ENGINEERS experienced in corrugated paper production. Application by letter. Salary not stated. Location, Brooklyn, N. Y. V–1068.

OPERATOR on corrugated paper machines. Application by letter. Salary about $40 per week to start. Location, Brooklyn, N. Y. V–1069.

SUPERINTENDENT thoroughly familiar with all kinds of plain and reinforced concrete, especially cinder concrete arch floor construction. Must also be able to estimate on this line. Application by letter only. Salary not stated. Location, New York City. V–1078.

STRUCTURAL ENGINEER, with ten years' experience in building work and industrial plant layout, for position in engineering organization in charge of work including plans, specifications, and estimates. No detail work involved and excellent opportunities for advancement. In addition to full technical qualifications must have good address and ability to meet employer's clients. Application by letter with full details of experience and recent photograph. Location, New England. V–1126.

STRUCTURAL ENGINEERS for structural steel and reinforced concrete design. Work includes all types of buildings from power houses to office buildings and churches. Want A–1 men who wish to connect with an organization offering advancement to proper parties. Application by letter, stating experience, salary requirements, earliest reporting date, and also submit some of recent work. Salary not stated. Location, Michigan. V–1152.

MEN AVAILABLE

SUPERVISING ENGINEER, with business and executive training; Graduate Civil Engineer; age 35. Experienced power and hydraulic man, and thoroughly qualified on buildings and heavy construction, both structural and mechanical features. CE–333.

CIVIL ENGINEER AND SUPERINTENDENT OF CONSTRUCTION, M. Am. Soc. C. E.; age 47; married. Twenty years in charge of construction and maintenance of railways, reconnaissance, location, design; construction of bridges and buildings; extensive experience on concrete and foundations. Also, 7 years on irrigation, drainage, and municipal work. Passed U. S. Civil Service examinations for Irrigation Engineer and for Supervising Engineer. Speaks and writes French fluently. Active, dependable; highest references. Will go anywhere, but prefers United States. Now available. CE–334.

PLANT ENGINEER, Assoc. M. Am. Soc. C. E.; Graduate Civil Engineer; age 33; married. Eleven years' experience in design and construction of complete plants for quarries, mines, and mills, including structures, equipment, power plants, transportation systems, etc. Capable of taking charge of all engineering for these plants. Personal interview desired. CE–335.

GRADUATE ENGINEER, Assoc. M. Am. Soc. C. E.; age 31; married. Eleven years' experience in reinforced concrete and structural steel design. Accustomed to the preparation of designs and estimates on all types of reinforced concrete buildings from preliminary architectural sketches. Speaks French and has had sales experience. Prefers position with Sales Organization or General Contractor. Now located in Philadelphia, Pa. Minimum salary, $275 to $300 per month. CE–336.

ENGINEER, Graduate School of Mines, Columbia University; M. Am. Soc. C. E., Am. Soc. Mech. Engrs., and Am. Inst. Min. and Metal. Engrs. Specialty, iron and steel manufacture. Long practical experience. Excellent record and references. Available especially for consulting work anywhere in United States or abroad. CE–337.

MILL ARCHITECT AND ENGINEER, Assoc. M. Am. Soc. C. E.; age 38; married. Fourteen years' experience designing pulp and paper mills with appurtenant hydraulic and steam-power developments. Capable of taking responsible charge of purchase and arrangement of equipment, architecture, structural design, power requirements, specifications, and contracts. CE–338.

ENGINEER-MANAGER, Assoc. M. Am. Soc. C. E., age 30, with thorough business training, desires permanent connection as Engineer or Executive with commercial, industrial, utility or other organization where future advancement is possible. New York or Eastern States preferred. Now permanently employed in responsible charge. Water Supply Company operation and construction. CE–339.

ANNOUNCEMENTS

The Reading Room of the Society is open from 9 A. M. to 6 P. M., and from 7 P. M. to 10 P. M., every day, except Sundays, New Year's Day, Washington's Birthday, Memorial Day, Fourth of July, Labor Day, Thanksgiving Day, and Christmas Day; during July and August, it is closed at 6 P. M.

FUTURE MEETINGS

June 7th, 1922.—8 P. M.—A regular business meeting of the Society will be held on the Fifth Floor of the Engineering Societies Building, at which the "Tentative Specifications for Steel Railway Bridges" will be presented for informal discussion.

These Tentative Specifications were submitted as a Progress Report of the Special Committee on Specifications for Bridge Design and Construction and published in *Proceedings* for December, 1921. Discussion on the Report is printed in the April, 1922, *Proceedings*.

ANNUAL CONVENTION

The Fifty-second Annual Convention of the Society will be held at the Hotel Wentworth, Portsmouth, N. H., on June 21st and 22d, 1922. A circular giving full information as to the general programme, transportation, hotel rates, etc., was issued on May 19th, 1922.

SCHOLARSHIP IN CIVIL ENGINEERING AT COLUMBIA UNIVERSITY

The governing bodies of Columbia University have placed at the disposal of the Society, a scholarship in Civil Engineering in the Schools of Mines, Engineering and Chemistry of Columbia University, beginning with the academic year 1922-23 and continuing until further notice. The scholarship pays $350 toward the annual tuition fees, which vary from $340 to $360, according to the details of the course selected. Re-appointment of the student to the scholarship for the completion of his course is conditioned upon the maintenance of a good standing in his work.

To be eligible for the scholarship, the candidate recommended will have to meet the regular admission requirements, in regard to which full information will be sent without charge upon application to the Secretary of the University or to the Secretary of the Society.

In a letter addressed to the Secretary of the Society, an applicant for this scholarship should set forth his qualifications (age, place of birth, education, statement of any other activities, such as athletics or working way through college, references, and photograph). A committee composed of Messrs. Robert Ridgway, C. W. Hudson, and J. P. H. Perry will consider the applications and will notify the authorities of Columbia University of their selection of a candidate. The last day for the filing of applications will be July 1st of each year.

The course at the Columbia Schools of Mines, Engineering and Chemistry is three years in length and is on a graduate basis. A candidate for admission must have had a general education, including considerable work in mathematics, physics, and chemistry. Three years of preparatory work in a good college or scientific school should be sufficient, if special attention has been given to the three preparatory subjects mentioned. A college graduate, with a Bachelor of Science degree in engineering, can generally qualify to advantage. The candidate is admitted on the basis of his previous collegiate record, and without undergoing special examinations. Other qualifications being equal, members of Student Chapters of the Society will be given preference.

The purpose of this advanced course is to produce a high type of engineer, trained in the humanities as well as in the fundamentals of his profession. It is hoped that members will show a keen interest in this scholarship, which will insure the choice of a candidate of the highest qualifications.

LOCAL SECTIONS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Section (Constitution Approved by Board, 1905).

Thomas H. Means, President; H. D. Dewell, Secretary-Treasurer, 503 Market Street, San Francisco, Cal.

Colorado Section (Constitution Approved by Board, 1909).

A. N. Miller, President; Thomas H. Olds, Secretary-Treasurer, First National Bank Building, Denver, Colo.

Atlanta Section (Constitution Approved by Board, 1912).

William C. Spiker, President; Frederick H. McDonald, Secretary-Treasurer, 1530 Healy Building, Atlanta, Ga.

Baltimore Section (Constitution Approved by Board, 1914).

Ezra B. Whitman, President; George S. Robertson, Sr., Secretary-Treasurer, 1628 Linden Avenue, Baltimore, Md.

Buffalo Section (Constitution Approved by Board, 1921).

Walter McCulloh, President; John H. Feigel, Secretary-Treasurer, 492 Minnesota Ave., Buffalo, N. Y.

Central Ohio Section (Constitution Approved by Board, 1921).

Frank W. Jennings, President; H. F. Schryver, Secretary, 405 New York Central Building, Columbus, Ohio.

Cincinnati Section (Constitution Approved by Board, 1920).

Edgar Dow Gilman, President; Alphonse M. Westenhoff, Secretary, 709 Gwynne Bldg., Cincinnati, Ohio.

Cleveland Section (Constitution Approved by Board, 1915).

A. V. Ruggles, President; George H. Tinker, Secretary-Treasurer, 516 Columbia Building, Cleveland, Ohio.

Connecticut Section (Constitution Approved by Board, 1919).

Harold W. Griswold, President; Clarence M. Blair, Secretary-Treasurer, 785 Edgewood Avenue, New Haven, Conn.

Dayton Section (Constitution Approved by Board, 1922).

Charles H. Paul, President; K. C. Grant, Secretary-Treasurer, Winters Bank Building, Dayton, Ohio.

Detroit Section (Constitution Approved by Board, 1916).

H. H. Esselstyn, President; Alex. Linn Trout, Secretary-Treasurer, 110 North Ingalls Street, Ann Arbor, Mich.

District of Columbia Section (Constitution Approved by Board, 1916).

Gratz B. Strickler, President; James H. Van Wagenen, Secretary-Treasurer, 2001 Sixteenth Street, N. W., Washington, D. C.

Duluth Section (Constitution Approved by Board, 1917).

John L. Pickles, President; Walter G. Zimmermann, Secretary, 203 Wolvin Building, Duluth, Minn.

Illinois Section (Constitution Approved by Board, 1916).

A. J. Hammond, President; W. D. Gerber, Secretary-Treasurer, 913 Chamber of Commerce, Chicago, Ill.

Iowa Section (Constitution Approved by Board, 1920).

J. H. Dunlap, President; R. W. Crum, Secretary, Care, Iowa State Highway Commission, Ames, Iowa.

Kansas City (Mo.) Section (Constitution Approved by Board, 1921).

John V. Hanna, President; Henry C. Tammen, Secretary-Treasurer, 1012 Baltimore Avenue, Kansas City, Mo.

Kansas Section (Constitution Approved by Board, 1920).

L. E. Conrad, President; Frank S. Altman, Secretary-Treasurer, 1114 Garfield Avenue, Topeka, Kans.

Los Angeles Section (Constitution Approved by Board, 1913).

Ralph J. Reed, President; Floyd G. Dessery, Secretary, 618 Central Building, Los Angeles, Cal.

Louisiana Section (Constitution Approved by Board, 1914).

Donald Derickson, President; F. A. Muth, Secretary, 224 Custom House Building, New Orleans, La.

Nashville Section (Constitution Approved by Board, 1921).

B. H. Klyce, President; L. C. Anderson, Secretary-Treasurer, Bridge Building, Nashville, Tenn.

Nebraska Section (Constitution Approved by Board, 1917).

William Grant, President; Homer V. Knouse, Secretary-Treasurer, 200 City Hall, Omaha, Nebr.

New York Section (Constitution Approved by Board, 1920).

Nelson P. Lewis, President; J. P. J. Williams, Secretary, 33 West 39th Street, New York City.

Northeastern Section (Constitution Approved by Board, 1921).

Frank B. Sanborn, Chairman; Charles W. Banks, Secretary, 715 Tremont Temple, Boston, Mass.

Northwestern Section (Constitution Approved by Board, 1914).

W. T. Walker, President; Paul C. Gauger, Secretary, 300 Endicott Building, St. Paul, Minn.

Oklahoma Section (Constitution Approved by Board, 1920).

Max L. Cunningham, President; R. E. Brownell, Secretary-Treasurer, 402 First National Bank Building, Oklahoma, Okla.

Philadelphia Section (Constitution Approved by Board, 1913).

Benjamin Franklin, President; S. C. Hollister, Secretary, 1200 Land Title Building, Philadelphia, Pa.

Pittsburgh Section (Constitution Approved by Board, 1918).

J. N. Chester, President; Nathan Schein, Secretary-Treasurer, 1510 Carson Street, Pittsburgh, Pa.

Portland (Ore.) Section (Constitution Approved by Board, 1913).

F. M. Randlett, President; C. P. Keyser, Secretary, 318 City Hall, Portland, Ore.

Providence (R. I.) Section (Constitution Approved by Board, 1920).

Sydney Wilmot, Chairman; Robert L. Brown, Secretary-Treasurer, 26 Sycamore Street, Providence, R. I.

St. Louis Section (Constitution Approved by Board, 1914).

E. B. Fay, President; William C. E. Becker, Secretary-Treasurer, 426 City Hall, St. Louis, Mo.

San Diego Section (Constitution Approved by Board, 1915).

P. R. Watson, President; J. Y. Jewett, Secretary-Treasurer, Administration Building, Balboa Park, San Diego, Cal.

Seattle Section (Constitution Approved by Board, 1913).

F. F. Sinks, President; Frank H. Fowler, Secretary-Treasurer, 1319 L. C. Smith Building, Seattle, Wash.

Spokane Section (Constitution Approved by Board, 1914).

C. A. Burnette, President; Charles E. Davis, Secretary-Treasurer, 401 City Hall, Spokane, Wash.

Texas Section (Constitution Approved by Board, 1913).

E. B. Cushing, President; E. N. Noyes, Secretary, 1107 Dallas County Bank Building, Dallas, Tex.

Toledo Section (Constitution Approved by Board, 1922).

M. J. Riggs, President; George N. Schoonmaker, Secretary-Treasurer, High-Pressure Fire Service Station, Cherry and Water Streets, Toledo, Ohio.

Utah Section (Constitution Approved by Board, 1916).

B. W. Matteson, President; H. S. Kleinschmidt, Secretary-Treasurer, 222 Felt Building, Salt Lake City, Utah.

Virginia Section (Constitution Approved by Board, 1922).

J. C. Carpenter, President; James F. MacTier, Secretary-Treasurer, 1312 Maple Avenue, Roanoke, Va.

STUDENT CHAPTERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS*

Stanford University.

R. I. Hill, President; John H. Colton, Corresponding Secretary, Box 121, Stanford, Calif.

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* By a recent ruling of the Board of Direction, the minimum membership of a Student Chapter has been fixed at 12 instead of 20.

Alabama Polytechnic Institute.

R. O. Davis, President; A. R. Harvey, Jr., Secretary-Treasurer, Box 661, Auburn, Ala.

Braune Civil Engineering Society (University of Cincinnati).

John W. Guilday, President; C. A. Harrell, Secretary of Section 10; R. Blickensderfer, Secretary of Section 20; University of Cincinnati, Cincinnati, Ohio.

Bucknell University.

Ralph F. Hartz, President; Donald A. Davis, Secretary, Bucknell University, Lewisburg, Pa.

California Institute of Technology.

W. M. Taggart, President; Douglas A. Stromsoe, Secretary, California Institute of Technology, Pasadena, Calif.

Carnegie Institute of Technology.

H. T. Ward, President; J. K. Elliott, Secretary, Carnegie Institute of Technology, Pittsburgh, Pa.

Clemson Agricultural and Mechanical College of South Carolina.

J. H. Baumann, President; W. J. Stribling, Secretary, Clemson Agricultural and Mechanical College of South Carolina, Clemson College, S. C.

Cornell University.

James Hannigan, President; Albert Lucas, Secretary-Treasurer, Lincoln Hall, Cornell University, Ithaca, N. Y.

Drexel Institute.

C. V. Nishwitz, Chairman; Raymond Radbill, Secretary, Drexel Institute, Philadelphia, Pa.

Georgia School of Technology.

F. H. Harrison, President; C. M. Kennedy, Jr., Secretary, 91 West North Avenue, Atlanta, Ga.

Iowa State College.

Raymond L. Whannel, President; C. La Verne Day, Secretary, Iowa State College, Ames, Iowa.

Johns Hopkins University.

W. A. Randall, President; I. M. Zeskind, Secretary, Johns Hopkins University, Baltimore, Md.

Lafayette College.

Douglas M. Brown, President; Ivan C. Blickenstaff, Secretary, Lafayette College, Easton, Pa.

Lehigh University

John N. Marshall, President; George R. Swinton, Lehigh University, Bethlehem, Pa.

Massachusetts Institute of Technology

George Eric Barnes, President; Ralph Rutherford Dresel, Secretary, 53 Brook Street, Brookline, Mass.

Montana State College.

Merrill J. Alquist, President; Emmett Moore, Secretary, 921 South Third Avenue, Bozeman, Mont.

New York University.

George H. Martin, President; Abram J. Jacobs, Secretary, 302 Gould Hall, New York University, New York City.

Norwich University.

J. H. Kane, President; Allen J. Hamilton, Secretary, Norwich University, Northfield, Vt.

Ohio State University.

O. W. Merrell, President; William M. Ruddicks, Secretary, 65 Thirteenth Avenue, Columbus, Ohio.

Oregon State Agricultural College.

Richard D. Slater, President; Wilbur H. Welch, Secretary, Oregon State Agricultural College, Corvallis, Ore.

Pennsylvania State College.

Arthur H. McFadden, President; William W. Seltzer, Secretary, Pennsylvania State College, State College, Pa.

Polytechnic Institute of Brooklyn.

W. C. Hanning, President; S. Lordi, Secretary, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.

Purdue University.

R. O. Edwards, President; W. C. Mason, Secretary-Treasurer, Purdue University, West Lafayette, Ind.

Rensselaer Polytechnic Institute.

William Minot Thomas, President; Earl D. Hopkins, Secretary, 147 Eighth Street, Troy, N. Y.

Rose Polytechnic Institute.

Robert Cash, President; F. Ray Martin, Secretary-Treasurer, Rose Polytechnic Institute, Terre Haute, Ind.

Rutgers College.

L. C. Kuhl, President; A. C. Ely, Secretary, 105 Winants Hall, Rutgers College, New Brunswick, N. J.

State University of Iowa.

James Fred Phillips, President; Louis E. Baggs, Secretary, State University of Iowa, Iowa City, Iowa.

Swarthmore College.

Frank Lemke, President; H. Chandlee Turner, Jr., Secretary, Swarthmore College, Swarthmore, Pa.

Syracuse University.

Arthur V. Dollard, Secretary, College of Applied Science, Syracuse University, Syracuse, N. Y.

University of California.

E. F. Sutherland, President; H. E. Hedger, Secretary, University of California, Berkeley, Calif.

University of Colorado.

Herbert Altvater, President; Charles Bowden, Secretary, 1229 University Avenue, Boulder, Colo.

University of Illinois.

A. L. R. Sanders, President; M. E. Jansson, Secretary, University of Illinois, Urbana, Ill.

University of Kansas.

W. W. Hoagland, President; Waldo G. Bowman, Secretary, 1106 Ohio Street, Lawrence, Kans.

University of Kentucky.

H. J. Beam, President; H. E. Glenn, Secretary-Treasurer, 348 Harrison Avenue, Lexington, Ky.

University of Maine.

Ian M. Rusk, President; Clarence B. Gould, Secretary, Sigma Phi Sigma House, University of Maine, Orono, Me.

University of Minnesota.

C. L. Swanson, President, 1716 Tyler Street, N. E., Minneapolis, Minn.

University of Missouri.

W. S. McDaniel, President; J. D. Sandker, Secretary, 407 West Broadway, Columbia, Mo.

University of Nebraska.

J. E. Applegate, President; W. H. Mengel, Secretary, University of Nebraska, Lincoln, Nebr.

University of North Carolina.

H. G. Baity, President; L. I. Lassiter, Secretary, University of North Carolina, Chapel Hill, N. C.

University of Pennsylvania.

Charles W. Foppert, President; Fred Welchy, Secretary, University of Pennsylvania, Philadelphia, Pa.

University of Pittsburgh.

L. W. Fletcher, President; J. M. Daniels, Secretary, University of Pittsburgh, Pittsburgh, Pa.

University of Texas.

Frank Cannon, President; Claude Riney, Secretary, 1908 Wichita Street, Austin, Tex.

University of Virginia.

Jack A. Gunn, Secretary and Treasurer, Box 428, University, Va.

University of Washington.

B. W. Brown, President; G. E. Large, Secretary, 4518 Eleventh Avenue, N. E., Seattle, Wash.

University of Wisconsin.

E. K. Loverud, President; L. H. Kessler, Secretary, 235 West Gilman Street, Madison, Wis.

Virginia Military Institute.

Benjamin F. Parrott, President; R. G. Hunt, Secretary-Treasurer, Virginia Military Institute, Lexington, Va.

Virginia Polytechnic Institute.

W. S. Miles, President; J. Byron Herring, Secretary, Virginia Polytechnic Institute, Blacksburg, Va.

Washington University Collimation Club.

William D. Rolfe, President; Erwin Bloss, Secretary, Washington University, St. Louis, Mo.

West Virginia University.

J. E. Wheeler, President; Milton Jarrell, Secretary, 113 Beverely Avenue, Morgantown, W. Va.

Worcester Polytechnic Institute.

Carl F. Meyer, President; Albert P. Haydon, Secretary, Worcester Polytechnic Institute, Worcester, Mass.

Yale University.

W. S. Moore, President; T. T. McCrosky, Secretary, Sheffield Scientific School, Yale University, New Haven, Conn.

NEW BOOKS*

(From April 1st, to April 29th, 1922)

The statements made in these notices are taken from the books themselves, and this Society is not responsible for them.

DONATIONS TO ENGINEERING SOCIETIES LIBRARY

PRINCIPLES OF ELECTRICAL ENGINEERING.

By William H. Timbie and Vannevar Bush. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1922. 513 pp., illus., 8 x 5 in., cloth. $4.00.

This textbook, written for students of college grade, with a knowledge of calculus and physics, aims to provide a substantial first course in the subject, which will present rigorously, yet in understandable form, the basic principles underlying modern electrical engineering, to be followed by detailed courses in direct and alternating-current machinery. Special features are the stressing of the subject of the magnetic circuit; the use of the electron theory as a basis for explanation; the inclusion of the subjects of thermionic emission, conduction through gases, electrolytic conduction, and high-frequency phenomena; a novel approach to the subject of the behavior of dielectrics; and numerous live problems.

CONTINUOUS WAVE WIRELESS TELEGRAPHY.

By B. E. G. Mittell. (Pitman's Technical Primers.) Lond. and N. Y., Sir Isaac Pitman & Sons, Ltd., 1922. 110 pp., illus., 7 x 4 in., cloth. 85 cents.

This little book is offered as an introduction to radiotelegraphy from the engineer's point of view. It avoids the use of mathematics and goes directly into the subject without a preliminary discourse on electricity or the development of mechanical analogies. Special attention, so far as space permits, is given to the Poulsen arc and to the construction of tall aerial structures, and useful references to important papers are given throughout the book.

AUTOMATIC TELEPHONE SYSTEMS.

By William Aitken. Vol. 1, Circuits and Apparatus as Used in the Public Services. Lond., Benn Brothers, Ltd., 1921. 282 pp., diagrams, 10 x 8 in., cloth. 25 shillings.

The great mass of detail and the complicated circuit diagrams required to present this subject to students make special treatment necessary. This book attempts to present the subject in intelligible form by re-arranging the diagrams, eliminating unnecessary crossing lines, simplifying the form, and presenting them in such a way as to show the relationship of the system as a whole. To accomplish these ends, a large page and a new system of describing the diagrams, which consists in numbering a circuit from end to end with the same system, have been used. The book covers the whole subject. The principal commercial systems and other less-known systems of promise are described.

DESIGN AND CONSTRUCTION OF OIL ENGINES.

By A. H. Goldingham. Fifth Edition. N. Y., Spon & Chamberlain; Lond., E. & F. N. Spon, 1922. 2 pt. in 1 v., illus., diagrams, 8 x 5 in., cloth. $4.00.

This treatise comprises two parts. The first part is entirely new and contains 141 pages devoted to high-compression oil engines, including solid injection, air-blast and modern two-cycle engines. The design and construction of the parts of these engines, testing, installation, and construction are considered, and the leading American and English designs are discussed. The second part relates to earlier types of low-compression oil engines. It is apparently a reprint of the fourth edition of the work, with the omission of the Appendix on Diesel engines, now included in a separate treatise on that subject.

PRINCIPLES OF MECHANICAL REFRIGERATION.

By H. J. Macintire. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. 252 pp., illus., diagrams, 8 x 6 in., cloth. $2.50.

Based on a "study course" of twenty articles published in *Power* during 1920, the book is intended to cover the entire field of refrigeration in an elementary manner, with little use of mathematics. Analogies to steam machinery and steam cycles are used to explain the action of refrigeration.

MECHANICAL STOKERS.

By Joseph G. Worker and Thomas A. Peebles. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. 258 pp., illus., tab., diagrams, 9 x 6 in., cloth. $3.00.

* Unless otherwise specified, books in this list have been donated by the publishers.

Although stokers are treated in books on boilers and power-plant equipment, there has been no work treating of them as a separate unit, until the appearance of the present volume. It discusses the phenomena of combustion in relation to stokers, describes mechanical stokers and modern practice in stoker installation and use, and discusses the selection of stokers for different fuels and differing conditions. The authors have endeavored to give reliable, unbiased opinions and facts from field experience in design, installation, and operation.

ANALYSIS OF FUEL, GAS, WATER, AND LUBRICANTS.

By S. W. Parr. Third Edition. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. 250 pp., illus., diagrams, tab., 8 x 6 in., cloth. $2.50.

This book was originally published for use by students of mechanical engineering, and provided a course intended to help the engineer to a better understanding of the literature of the topics treated, and also to an appreciation and more intelligent use of data supplied by the chemist. The present edition has been expanded to meet the needs of students of chemistry as well. It contains a synopsis of the author's lectures on fuel, gas, water and lubricants, and a course in laboratory methods for their analysis.

WELL-BORING FOR WATER, BRINE, AND OIL.

By C. Isler. Third Edition. Lond., E. & F. N. Spon, Ltd.; N. Y., Spon & Chamberlain, 1921. 259 pp., illus., diagrams, 9 x 6 in., cloth. $4.80.

The author describes various methods of boring and drilling in search of water, brine, oil, or minerals, including driven and bored tube wells; the Kind-Chaudron, Dru and Mather and Platt deep-boring systems; the American rope-boring system, and diamond-drilling. Methods of raising water are dealt with. This edition is revised and includes the methods developed during recent years.

GENERAL ECONOMIC GEOLOGY.

By William Harvey Emmons. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. 516 pp., illus., 9 x 6 in., cloth. $4.00.

This volume is an introduction to the study of mineral deposits, for use by students with a knowledge of the elements of general geology and mineralogy. It embraces the geology of mineral fuels, structural materials, and other non-metals, and of the metals. The first chapter includes introductory matter, definitions, and an outline of the classification of mineral deposits. It is followed by a treatment of coal, petroleum, and the solid bitumens. Then follows a more detailed discussion of the classification and genesis of mineral deposits, which is succeeded by sections on non-metals and metals. Numerous footnotes call attention to the principal sources of information on each topic.

ABRISS DER LEHRE VON DEN ERZLAGERSTATTEN.

Von Richard Beck, bearbeitet durch Georg Berg. Berlin, Gebrüder Borntraeger, 1922. 408 pp., illus., 10 x 7 in., paper. $3.60.

During his latter years Dr. Beck had in mind the preparation of an abridgment of his well-known treatise on ore-deposits which would be suitable as a college textbook and a survey of the principal information on the subject for use by geologists whose chief interests lie along other lines. With this in view, he had corrected and annotated a copy of the third edition of the treatise, when his death in 1919 made it necessary to entrust the preparation of the present work to Mr. Berg, one of his earliest assistants. This outline is approximately one-third the size of the original work, which it follows in plan and arrangement. Condensation has been effected in the different chapters by bringing together the less important occurrences, that are interesting for geological or other reasons, as examples in a general description of the corresponding groups of deposits. The number of ore formations has been reduced by combining certain groups, and the chapter on epigenetic deposits has been shortened.

METRIC SYSTEM FOR ENGINEERS.

By Charles B. Clapham. (Directly-Useful Technical Series.) N. Y., E. P. Dutton & Co., 1922. 181 pp., 9 x 6 in., cloth. $6.00.

This book is not concerned with the controversy regarding the metric system. Its object is to give a full, practical explanation of the system as it is met in engineering calculation and measurement, for use by draftsmen, mechanics, and engineers. After an introduction explaining basic principles, the simple measures of length, area, volume, capacity, and weight are discussed, with special attention to the usual measuring tools found in workshops and drafting rooms. Compound measures used in engineering are then described, with the derivation of the corresponding British equivalents. Succeeding chapters give tables of the more common engineering constants in British and metric units, and examples of the alteration of numerical constants in formulas when metric values are to be used.

INTRODUCTION TO ELECTRO-DYNAMICS.

By Leigh Page. Boston and N. Y., Ginn & Co., 1922. 134 pp., 8 x 6 in., cloth. $2.00.

The object of this book is to present a logical development of electro-magnetic theory founded on the principle of relativity. So far as the author is aware, the universal procedure has been to base the electro-dynamic equations on the experiments of Coulomb,

Ampère, and Faraday, even books on the principle of relativity going no farther than to show that these equations are co-variant for the Lorentz-Einstein transformation. As the dependence of electro-magnetism on the relativity principle is more intimate than this co-variance suggests, he believes it more logical to derive the electro-magnetic equations directly from this principle. The book covers topics appropriate for a one-year graduate course in electro-dynamics and electro-magnetic theory of light. It should interest those who are looking for a logical rather than a historical account of the science.

ORGANIC CHEMISTRY.

By Victor von Richter. Vol. 2: Chemistry of the Carbocyclic Compounds. Phila., P. Blakiston's Son & Co., 1922. 760 pp., 9 x 6 in., cloth. $8.00.

After an interval of six years since the appearance of the first volume, the second volume of this translation, dealing with the carbocyclic or closed carbon chain compounds, is now available. The translation follows the 11th German edition, prepared in 1912. The outstanding feature of this work is the large number of compounds listed, with outlines of the methods for preparing them and accounts of their important properties. No other book of its size gives such an exhaustive list. Because of this comprehensiveness, the book is most useful for reference, particularly when the large encyclopedias are not accessible.

CRAIN'S MARKET DATA BOOK AND DIRECTORY OF CLASS, TRADE,

And Technical Publications. Second Edition. Chic., G. D. Crain, Jr., 1922. 456 pp., 9 x 6 in., cloth. $5.00.

This is a reference book for advertisers. An account of trade, industry, and profession is given, which presents the statistical and marketing data necessary to give the advertiser or merchant a picture of the field as a whole. Each account is supplemented by a full list of American trade journals devoted to that industry, with their addresses, circulation, advertising rates, etc. A list of important foreign trade journals is included.

ESSAI D'OPTIQUE SUR LA GRADATION DE LA LUMIÈRE.

By Pierre Bouguer. (Les Maîtres de la Pensée Scientifique.) Paris, Gauthier-Villars et Cie., 1921. 129 pp., 7 x 5 in., paper. 3 francs.

This classic of the literature of optics is an account of Bouguer's study of certain important optical problems connected with the radiation of light and its absorption by various substances. It is the work which first set forth the basis of photometry, and led to the invention of the photometer by the author in 1748. The present edition reproduces the original text of 1729.

DONATIONS TO READING ROOM

PULLING TOGETHER.

By John T. Broderick. With Introduction by Charles P. Steinmetz. Schenectady, N. Y., Robson & Adee, 1922. 141 pp., 7½ x 5 in., cloth. $1.00.

The author of this work has had exceptional opportunities for the study of industrial problems, and discusses the great question before the industrial world of to-day, that of conciliation and co-operation of labor and capital. The book is written in a style interesting to the average reader as well as to industrial managers and engineers.

COLLECTED PAPERS ON ACOUSTICS.

By Wallace Clement Sabine. Cambridge, Harvard University Press; Lond., Humphrey Milford, 1922. 279 pp., illus., diagrams, 10¼ x 7½ in., cloth. $4.00.

This book is a compilation of all the important contributions to the subject of architectural acoustics written by the author most of which have appeared previously in various architectural journals.

MEMBERSHIP

(From April 5th to May 2d, 1922)

ADDITIONS

MEMBERS

Member	Grade	Date of Membership.
ADAMS, LEWIS MILTON. Maj., Corps of Engrs., U. S. A.; Dist. Engr., Galveston, Tex.		April 3, 1922
ANDERBERG, EDWARD. Senior Asst. Engr., Barge Canal Terminals, Pier 6, East River, New York City.	Jun. Assoc. M. M.	Mar. 5, 1907 Mar. 1, 1910 April 4, 1922
BELL, JOSEPH EDGAR. Engr., The Montana Power Co., Butte, Mont.	Assoc. M. M.	Oct. 3, 1911 April 4, 1922
CONVERSE, JOSEPH BRANDLY. Cons. Engr., 700-B Interstate Bank Bldg., New Orleans, La.	Assoc. M. M.	May 15, 1917 April 4, 1922
COWPER, JOHN WHITFIELD. Pres., The John W. Cowper Co., Fidelity Bldg., Buffalo, N. Y.	Jun. Assoc. M. M.	June 21, 1894 Oct. 2, 1901 April 4, 1922
CRANDALL, LYNN. Water Commr. for Big Lost River, Mackay, Idaho	Jun. Assoc. M. M.	Dec. 6, 1910 April 7, 1915 April 4, 1922
CURTISS, CHARLES DWIGHT. Senior Highway Engr., U. S. Bureau of Public Roads, Washington, D. C.		April 3, 1922
DIGNUM, HARRY JOCELYN. Supt. of Railroads, Transportation, and Eng., Baragua Sugar Co., Baragua, Camaguey, Cuba	Assoc. M. M.	April 2, 1913 April 4, 1922
DOUGHERTY, NATHAN WASHINGTON. Prof., Civ. Eng., Univ. of Tennessee, Knoxville, Tenn.	Assoc. M. M.	Jan. 13, 1919 April 4, 1922
DOUSMAN, JAMES HOPKINS. (Dousman Pump & Machinery Co.), 318 Reliance Bldg., Kansas City, Mo.		April 3, 1922
FOWLER, JAMES DUNCAN. Cons. Engr. (Koch & Fowler), 606 Sumpter Bldg., Dallas, Tex.	Assoc. M. M.	Oct. 7, 1914 Nov. 21, 1921
FRAZIER, FORREST FAYE. Associate Prof., Civ. Eng., Kansas State Agricultural Coll., Manhattan, Kans.	Assoc. M. M.	May 31, 1916 April 4, 1922
FREELAND, FRANCIS EUGENE. Pres., Freeland Roberts Co., 1212 Independent Life Bldg., Nashville, Tenn.	Assoc. M. M.	Sept. 3, 1913 April 4, 1922
HARVEY, FORREST SHEPHERD. Res. Engr., Representing Chas. T. Main and The Am. Sugar Refining Co., 836 Park Ave., Baltimore, Md.		April 3, 1922
HOPPIN, WILLIAM PIERCE. Asst. Engr., James Walker, 839 Edison Bldg., Chicago, Ill.		April 3, 1922
HURLBUT, WILLIAM WHITEHEAD. Office Engr., Bureau of Water Works and Supply, City of Los Angeles (Box 497), M. O., Los Angeles, Calif.	Assoc. M. M.	Sept. 3, 1913 April 4, 1922
JOHNSTON, EDWARD NEELE. Lt.-Col., Corps of Engrs., U. S. A., U. S. Engr. Office, Room 405, Customhouse, Cincinnati, Ohio.		Oct. 10, 1921
KOSS, GEORGE WALTHER. Pres. and Gen. Mgr., Koss Constr. Co., Des Moines, Iowa	Assoc. M. M.	June 6, 1911 April 4, 1922
LABOON, JOHN FRANCIS. Hydr. and San. Engr. (The J. N. Chester Engrs.), 1111 Union Bank Bldg., Pittsburgh, Pa.	Assoc. M. M.	April 14, 1919 April 4, 1922

MEMBERS—(*Continued*)

		Date of Membership.
LAMBE, CLAUDE MILTON. Res. Engr., Joint Bldg. Committee, Box 640, Raleigh, N. C.	Assoc. M. M.	Dec. 6, 1915 April 4, 1922
LANAGAN, FRANK RAY. City Engr. (Res., 114 Chestnut St.), Albany, N. Y.	Jun. Assoc. M. M.	Sept. 5, 1905 Feb. 1, 1910 April 4, 1922
PRESTON, PORTER JOHNSTONE. Project Mgr., U. S. Reclamation Service, Yuma, Ariz.		April 3, 1922
ROSS, ROBERT JOHN. Asst. City Engr., Municipal Bldg., Hartford, Conn.	Assoc. M. M.	May 7, 1913 April 4, 1922
SCHUBERT, CHARLES WESLEY. Engr. for R. C. Products Trust, 17837 Landseer Rd., Cleveland, Ohio.	Assoc. M. M.	Aug. 31, 1909 April 4, 1922
SECREST, THOMAS WILLIAM. Supt. of Constr., Alaskan Eng. Comm., 606 Diamond Ave., Hillyard, Wash.	Assoc. M. M.	April 17, 1917 April 4, 1922
SMITH, WALTER DORR. Asst. Engr., City Engr.'s Office, 4561 Glen Albyn Drive, Los Angeles, Calif.	Assoc. M. M.	June 30, 1911 Jan. 20, 1922
TRAUGOTT, ALBERT MASER. Asst. Chf. Engr., The Virginian Ry., Terminal Bldg., Norfolk, Va.		April 3, 1922
VERVEER, EMANUEL LOUIS. Cons. Engr., 25 Church St. (Res., 600 West 179th St.), New York City.	Assoc. M. M.	June 3, 1903 April 4, 1922
WATSON, MARTIN WALLACE. State Highway Engr. of Kansas, Care, State Highway Comm., Topeka, Kans.	Assoc. M. M.	Jan. 13, 1919 April 4, 1922
WIGHT, FRANK CLINTON. Managing Editor, *Engineering News-Record*, Tenth Ave., at 36th St., New York City (Res., 32 Waldron Ave., Summit, N. J.)		April 3, 1922
WILDER, ELLWOOD COGGESHALL. Engr., Dept.; Water and Sewers, 1718 Anapuni St., Honolulu, Hawaii.	Jun. Assoc. M. M.	June 30, 1910 May 13, 1918 Jan. 20, 1922
WINN, GEORGE PHILIP. City Engr., Municipal Bldg., Nashua, N. H.	Assoc. M. M.	Aug. 31, 1915 April 4, 1922

ASSOCIATE MEMBERS

AKERS, EDWIN RYAN. Reinforced Concrete Designer, Frederick Snare Corporation, Box 733, Havana, Cuba	Jun. Assoc. M.	July 6, 1920 April 3, 1922
BARBER, CHARLES WIGHTMAN. 3428 Brown St., N. W., Washington, D. C.	Jun. Assoc. M.	Nov. 3, 1915 April 3, 1922
BARKER, HAROLD WARD. Structural Engr., George D. Mason & Co., 1534 Dime Bank Bldg., Detroit, Mich.		April 3, 1922
BOYLE, FRANCIS ALOYSIUS. With Thomas E. Murray, Inc., 55 Duane St. (Res., 1283 Morris Ave.), New York City.		April 3, 1922
BRAVERMAN, SIGMUND. Designing Engr., Swirsky & Miller, 600 Herberich Bldg., Akron, Ohio.		April 3, 1922
BROWN, LEO FRANCIS. Care, J. C. Brackenridge, 95 Liberty St., New York City (Res., 1206 New York Ave., Brooklyn, N. Y.)	Jun. Assoc. M.	Sept. 10, 1918 April 3, 1922
CLARK, MILES ELLIOTT. Asst. Engr., Dept. of Public Works, State of Washington, Olympia, Wash.		Nov. 21, 1921

ASSOCIATE MEMBERS—(*Continued*)

		Date of Membership.
Clinger, Robert Henry. 905 Main St. (Res., 221 Pembroke Ave.), Dallas, Tex		April 3, 1922
Copeland, Robert Morris. Capt., Corps of Engrs., U. S. A., Camp A. A. Humphreys, Va. (Res., 1470 Munroe St., Denver, Colo.)	Jun. Assoc. M.	Dec. 2, 1914 Jan. 14, 1922
Cummings, Albert Edward. Office Engr., Raymond Concrete Pile Co., 111 West Monroe St., Room 1912, Chicago, Ill		April 3, 1922
Dockstader, Ernest Ambrose. Engr., Structural Div., Stone & Webster, Inc., 147 Milk St., Boston 5, Mass		April 3, 1922
Donald, John Arnold. Asst. Engr. with City Engr., City Engr.'s Office, Wichita Falls, Tex		April 3, 1922
DuBois, Robert Sewall. Bridge Engr., Colorado State Highway Dept., Denver, Colo		April 3, 1922
Etchison, Bowie Griffith. Dist. Engr., Kanawha County, Court House (Res., 28 California Pl.), Charleston, W. Va		April 3, 1922
Fenner, John Sherrod. Res. Engr., Bartlett & Ranney, Inc., Kaufman, Tex		April 3, 1922
Foster, Henry Alden. Asst. Engr., New York Water Power Investigation, 205 Garfield Pl., South Orange, N. J		April 3, 1922
Froseth, Olaf. Asst. Engr., Ill. Cent. R. R., 4700 North Sacramento Ave., Chicago, Ill		April 3, 1922
Fuleihan, Nasri Suleman. Care, The Standard Oil Co. of New York, Box 286, Jerusalem, Palestine.	Jun. Assoc. M.	Dec. 2, 1914 April 3, 1922
Fulkman, John Alexander. Senior Asst. Engr., Morris Knowles, Inc., Care, Elyria Water-Works, Lorain, Ohio		Nov. 21, 1921
Gaedcke, Charles Henry. Draftsman, Standard Oil Co., 533 Muriel Parkway, Elizabeth, N. J		April 3, 1922
Gaynor, John Henry. Care, Dexter Portland Cement Co., Nazareth, Pa		April 3, 1922
Gibboney, Harry Simmerman. Dist. Mgr., Southern Office, National Steel Fabric Co., 604 Walton Bldg., Atlanta, Ga		April 3, 1922
Goodman, Charles Riviere. Asst. County Engr., Westcott Eng. Co., Box 757, Orange, Tex		April 3, 1922
Hemple, Henry William. Junior Hydrographic and Geodetic Engr., U. S. Coast and Geodetic Survey, 1120 Columbia Rd., N. W., Washington, D. C		April 3, 1922
Holmboe, Lawrence Scofield. Contr. and Engr. (The Holmboe Co.), 424 West 2d St., Oklahoma, Okla.	Jun. Assoc. M.	April 18, 1916 April 3, 1922
Hopkins, Alfred Turrill. Asst. Valuation Engr., M. C. R. R., 351 M. C. R. R. Terminal, Detroit, Mich		April 3, 1922
Howren, William Davis. Box 72, Amarillo, Tex	Assoc. M.	April 3, 1922
Idle, Leonard Augustus. 813 West Grand Ave., Oklahoma, Okla.		April 3, 1922
Jemison, Lawrence Lee. Bridge Engr., West Virginia State Road Comm., 16 California Pl., Charleston, W. Va		April 3, 1922
Johnston, Wardell D. County Engr., Black Hawk County, Waterloo, Iowa		April 3, 1922
Jones, Ernest Lester. Director, U. S. Coast and Geodetic Survey, Washington, D. C		April 3, 1922

ASSOCIATE MEMBERS—(*Continued*)

		Date of Membership.
LAMB, JOHN LONSDALE. 660 Warren St., Brooklyn, N. Y.		April 3, 1922
LARSON, EDWARD GUSTAF. 1 Granite St., Groton, Conn.		April 3, 1922
LOWERY, JOHN, JR. 84 Leicester Court, Detroit, Mich.	Jun.	Jan. 6, 1915
	Assoc. M.	April 3, 1922
McCLEVY, WILLIAM WILLSON. Asst. Dist. Engr., Virginia State Highway Comm., Box 215, Roanoke, Va.		April 3, 1922
McLEAN, JOHN ALEXANDER. City Engr., Box 227, Crookston, Minn.		April 3, 1922
MERRY, AUGUSTUS BRADFORD. 2427 Camp St., New Orleans, La.		April 25, 1921
MORGAN, NATHAN WILSON. Draftsman and Designer, Colorado State Highway Dept., Denver, Colo.		April 3, 1922
MORRIS, EARLE HEDDERICH. Chf. Engr., Board of Railroad Commrs., Box 446, Bismarck, N. Dak.		April 3, 1922
NEWMAN, JAMES BLAINE. Asst. Prof., Architecture and Architectural Eng., Univ. of Michigan, 1221 Williard St., Ann Arbor, Mich.		April 3, 1922
NEWSOM, REEVES JOSE. Commr. of Water Supply, City of Lynn, 11 Hovey Terrace, Lynn, Mass.		April 3, 1922
OGLE, FRANK BENJAMIN. Res. Engr. in Chg., Highway Design, Coleman County, Box 545, Coleman, Tex.		April 3, 1922
OLMSTEAD, CHARLES HAROLD. Div. Engr., State Highway Dept., 1401 Beechwood Ave., Nashville, Tenn.		Nov. 21, 1921
ORR, HARRY CONNELLY. Supt., San. and Drainage Comm., 39 Broad St., Room 20, Charleston, S. C.		April 3, 1922
RASMUSSEN, ALVIN CHRISTIAN. Chf. Engr., Insley Mfg. Co., 5135 Central Ave., Indianapolis, Ind.	Jun.	Feb. 4, 1913
	Assoc. M.	April 3, 1922
SCHILLING, FRANK ADAM. Engr. and Contr., 636 North Harvard Boulevard, Los Angeles, Calif.		Nov. 21, 1921
SHIELDS, PAUL REVERE. (J. B. Allen Eng. Co.), Hazard, Ky.		Oct. 10, 1921
SIMPSON, WILLARD EASTMAN. (W. E. Simpson Co.), 414 National Bank of Commerce Bldg. (Res., 1211 West Woodlawn Ave.), San Antonio, Tex.		April 3, 1922
STONE, NELSON. Constr. Engr. (Stone & Woelfel, Inc.), 708 Maryland Ave., Syracuse, N. Y.		April 3, 1922
TALBOT, FRANK DEWITT. Structural and Concrete Designer, Filtration Works, City of Sacramento, 1125 L St., Sacramento, Calif.		April 3, 1922
VAN COTT, GEORGE HENRY. Engr. in Chg. of Constr., Lewis & Valentine Co., 47 East 34th St., New York City (Res., Glen Head, N. Y.)		Oct. 10, 1921
WASSON, JOSEPH HOUSTON. Field Engr., Portland Cement Assoc., 1108 West Lewanee St., Lansing, Mich.		April 3, 1922
WHITE, WARREN GARDNER. Nevada, Iowa		April 3, 1922
WILCOX, FRANK DAY. Computer and Draftsman, Southern California Edison Co., 843 South Bonnie Brae, Los Angeles, Cal.		April 3, 1922
WILSON, NORMAN KENNETH. 415 M. & M. Bank Bldg. (Res., 1614 Grand Ave.), Milwaukee, Wis.	Jun.	Sept. 10, 1918
	Assoc. M.	April 3, 1922

JUNIORS

BARTON, CARL OSBORN. Asst. Engr., Board of Water Commrs., 176 East Jefferson Ave., Detroit, Mich.		April 3, 1922

JUNIORS—(*Continued*)

	Date of Membership.
BIEHLER, KARL FERDNAND. Asst. Supt., Llewellyn Iron Works, Los Angeles, Calif.	April 3, 1922
DELEHANTY, WILLIAM BENEDICT. Borough Engr., Edgewater, N. J.	April 3, 1922
FREESE, SIMON WILKE. Asst. to County Highway Engr., 119 West Washington St., Paris, Tex.	April 3, 1922
GLIDDEN, JOSEPH HENRY. Asst. to County Engr., Kittitas County, Ellensburg, Wash.	April 3, 1922
GOLDMAN, BENJAMIN SHEPPARD. 460 Glenmore Ave., Brooklyn, N. Y.	April 3, 1922
HENDRY, JAMES HORACE. Chf. Asst. in Chg., Civ. Eng., The Hartford Elec. Light Co., 90½ Brook St., Hartford, Conn.	April 3, 1922
LAUTERHAHN, OTTO. 117 South Montgomery St., Trenton, N. J.	April 3, 1922
MOYER, RALPH ALTON. Instr., Iowa State Coll., 816 Grand Ave., Ames, Iowa	April 3, 1922
PENNYBACKER, PERCY VIVIAN. 2606 Whitis Ave., Austin, Tex.	April 3, 1922
SCOVILLE, JOHN ALLEN. Lieut. (Senior Grade), C. E. C., U. S. N., Public Works Dept., Navy Yard, Mare Island, Vallejo, Calif.	April 3, 1922

REINSTATEMENTS

ASSOCIATE MEMBERS

	Date of Reinstatement.
BARKER, CHARLES WHITNEY TILLINGHAST	April 5, 1922

RESIGNATIONS

MEMBERS

	Date of Resignation.
DUFRESNE, ALEXANDER RITCHIE	April 18, 1922

ASSOCIATE MEMBERS

BRYAN, GEORGE, JR.	April 18, 1922
HERMAN, RALPH EMERSON, JR.	April 18, 1922
JOHNSON, LOUIS RAUB	April 18, 1922
MILLER, DEMONT GEORGE	April 18, 1922
MURPHY, EDWARD THEOBALD	April 18, 1922
PRICE, JOSEPH PAUL	April 18, 1922
SWETT, EVERETT HAROLD	April 18, 1922
WALKER, WILLIAM KEMP	April 18, 1922

JUNIORS

BAUER, JOHN, JR.	April 18, 1922

DEATHS

CHESLEY, FRANK EPHRAIM. Elected Associate Member, December 31st, 1913; died January 9th, 1922.

DAVIS, GEORGE ROBERT. Elected Associate Member, April 3d, 1907; died March 31st, 1922.

FOSTER, WILBUR FISK. Elected Member May 7th, 1873; died March 27th, 1922.

JENCKES, LAWRENCE BATES. Elected Junior, March 31st, 1891; Associate Member, October 7th, 1896; Member, September 6th, 1910; died March 29th, 1922.

DEATHS—(*Continued*)

KLINGNER, LOUIS WILLIAM. Elected Junior, October 31st, 1911; Associate Member, June 24th, 1914; died April 2d, 1922.

LANTZ, CLARENCE IVAN. Elected Associate Member, October 1st, 1913; died September 4th, 1921.

NEUDECKER, EMERET CLAUDE. Elected Associate Member, April 19th, 1920; died June 8th, 1921.

MORSE, CHARLES MILLER. Elected Member, January 2d, 1895; date of death unknown.

STEVENS, HORACE EDWARD. Elected Junior, November 1st, 1876; Member, April 4th, 1888; died February 15th, 1922.

Total Membership of the Society, May 2d, 1922,
10 330.

CURRENT CIVIL ENGINEERING LITERATURE

KEY TO ABBREVIATED REFERENCES TO PUBLICATIONS INDEXED*

Abbreviated References.	Publication.	Place.
Am. C. Inst.	*American Concrete Institute, Proceedings* (Y.)	Detroit
A. I. E. E.	*American Institute of Electrical Engineers, Journal* (M.)	New York
A. R. E. A.	*American Railway Engineering Association, Proceedings* (Y.)	Chicago
A. S. T. M.	*American Society for Testing Materials, Proceedings* (Y.)	Philadelphia
Am. Soc. C. E.	*American Society of Civil Engineers, Proceedings* (M.)	New York
Am. Soc. Mun. Impvts.	*American Society for Municipal Improvements, Proceedings* (Y.)	New York
Am. W. W. Assoc.	*American Waterworks Association, Journal* (Bi-M.)	Baltimore
Am. Wood Prs. Assoc.	*American Wood Preservers Association, Proceedings* (Y.)	Baltimore
Ann. P. et C.	*Annales des Ponts et Chaussées* (Bi-M.)	Paris
Ann. T. P. Belg.	*Annales des Travaux Publics de Belgique* (Bi-M.)	Brussels
Assoc. Ing. Gand	*Annales de l'Association des Ingénieurs sortis des Ecoles Spéciales de Gand* (Q.)	Ghent
Bost. Soc. C. E.	*Boston Society of Civil Engineers, Journal* (M.)	Boston
Can. Engr	*Canadian Engineer* (W.)	Toronto
Cem. Eng.	*Cement and Engineering News* (M.)	Chicago
Cornell C. E.	*Cornell Civil Engineer* (M.)	Ithaca
Dock & Harbour	*Dock and Harbour Authority* (M.)	London
Eisenbau	*Der Eisenbau* (M.)	Leipsig
Eng.	*Engineering* (W.)	London
Eng. Club, St. L.	*Engineers Club, St. Louis, Journal* (Bi-M.)	St. Louis
Eng. & Contr.	*Engineering and Contracting* (W.)	Chicago
Eng. Inst. Can.	*Engineering Institute of Canada, Journal* (M.)	Montreal
Eng. N. R.	*Engineering News-Record* (W.)	New York
Engrs. Soc. Pa.	*Engineers' Society of Pennsylvania, Journal* (M.)	Harrisburg
Engrs. Soc. W. Pa.	*Engineers' Society of Western Pennsylvania, Journal* (M.)	Pittsburgh
Engr.	*Engineer* (W.)	London
Engrs. & Eng.	*Engineers and Engineering, Engineers' Club of Philadelphia* (M.)	Philadelphia
Gen. Civ.	*Le Génie Civil* (W.)	Paris
Gesund. Ing.	*Gesundheits Ingenieur* (W.)	Munich
Inst. C. E.	*Institution of Civil Engineers Minutes of Proceedings* (Q.)	London
Inst. Mun. & Co. Engrs.	*Institution of Municipal and County Engineers, Journal* (W.)	London
Int. Ry. Assoc.	*International Railway Association, Bulletin* (M.)	Brussels
Land. Arch.	*Landscape Architecture* (M.)	Harrisburg
Mech. Eng.	*Mechanical Engineering* (M.) *Journal of the American Society of Mechanical Engineers*	New York
Mil. Engr.	*Military Engineer* (M.)	Washington
Min. & Metal.	*Mining and Metallurgy* (M.) *American Institute of Mining Engineers*	New York
Mun. & Co. Eng.	*Municipal and County Engineering* (M.)	Indianapolis
N. E. W. W. Assoc.	*New England Water Works Association, Journal* (M.)	Boston
N. Y. R. R. Club	*New York Railroad Club, Proceedings* (M.)	Brooklyn
Oest. Ing. Arch. Ver.	*Oesterreichischer Ingenieur und Architekten Verein, Zeitschrift* (W.)	Vienna
Power	*Power* (W.)	New York
Rev. Gen.	*Revue Générale des Chemins de Fer* (M.)	Paris
Ry. Age	*Railway Age* (W.)	New York
Ry. Main. Engr.	*Railway Maintenance Engineer* (M.)	Chicago
Ry. Rev.	*Railway Review* (W.)	Chicago
Schw. Bauz.	*Schweizerische Bauzeitung* (W.)	Zurich
Sci. Am.	*Scientific American* (M.)	New York
Soc. Ing. Civ. Fr.	*Société des Ingénieurs Civils de France, Mémoires et Comptes Rendus* (Q.)	Paris
Ver. deu. Ing.	*Verein deutscher Ingenieure, Zeitschrift* (W.)	Berlin
West. Ry. Club	*Western Railway Club, Proceedings* (M.)	Chicago
West. Soc. Engrs.	*Western Society of Engineers, Journal* (M.)	Chicago
Zeit. Bau.	*Zeitschrift fur Bauwesen* (Q.)	Berlin
Z. d. Bauver	*Zentralblatt der Bauverwaltung* (Semi-Weekly)	Berlin

* Y = Yearly ; Q = Quarterly ; M = Monthly ; F = Fortnightly ; W = Weekly.

A. Applied Sciences

a. Processes of Calculation

2. Graphical and Nomographical Processes

Graphical Determination of Azimuth.* W. Norman Thomas. Inst. Mun. & Co. Engrs. Mar. 25, '22.

B. Applied Mechanics

a. Mechanics of Solids (Strength of Materials)

2. Elastic Solids

Das Verhalten mechanisch beanspruchter Metalle.* (The Behavior of Metals Under Mechanical Loads.) E. Honneger. Eisenbau. Serial beginning Mar. '22.

Berechnung dünnwandiger Drehkörper auf Biegung.* (Calculation of Thin-walled Bodies of Revolution as to Flexure.) F. K. Th. van Jterson. Ver. deu. Ing. Mar. 4, '22.

Verdrehungsschwingungen und ihre Dampfung.* (Fluctuations in Torque and Their Limitations.) L. Gümbel. Ver. deu. Ing. Mar. 18. '22.

4. Riveted Systems

Beitrag zur Berechnung der Nebenspannungen.* (Contribution to the Calculation of Secondary Stresses.) K. Tsalyscheff. Eisenbau Mar. '22.

b. Hydraulics

1. Processes of Measurement

Expériences sur des Déversoirs à Nappe Libre avec Contraction Latérale.* (Experiments on Sharp Crested Weirs with Lateral Contraction.) V.-M. Hegly. Ann. P. et C. Nov.-Dec. '21.

Bestimmung von stromenden Gas- und Flussigkeitsmengen aus dem Druckabfall in Rohren.* (Determination of the Quantity of Flowing Gas or Liquids from the Loss in Pressure in Pipes.) Max Jakob. Ver. deu. Ing. Feb. 25, '22.

3. Industrial Hydraulics

Water Power Resources of Canada. J. T. Johnson. Can. Engr. Mar. 28, '22.

Hydroelectric Installation on the Kern River.* Ely C. Richardson. Mech. Eng. Apr. '22.

Surge Tanks.* B. F Jakobsen. Am. Soc. C. E. Apr. '22.

Test Code for Hydraulic Power Plants and Their Equipment.* A. S. M. E. Committee on Power Test Codes. Mech. Eng. Apr. '22.

The American Mixed-Flow Turbine and Its Setting.* Arthur T. Safford and Edward Pierce Hamilton. Am. Soc. C. E. Apr. '22.

Hydro-Electric Power Situation at St. John. Can. Engr. Apr. 4, '22.

Placing 410 000 Cu. Yd. of Concrete on Ontario's Niagara Power Development.* A. C. D. Blanchard and R. B. Young. Eng. N. R. Serial beginning Apr. 6, '22.

Smoky Falls Development on the Sturgeon River.* C. C. Irvine. Can. Engr. Apr. 11, '22.

Design of Sand Box for Kern River Hydro-Electric Plant.* Eng. N. R. Apr. 13, '22.

Excursion de la Société des Ingénieurs Civils en Dauphiné en Provence et à Marseille: Partie Electricité.* (Excursion of the Société des Ingénieurs Civils to Dauphiné, Provence and Marseille: Electrical Section.) L. Bellot. Soc. Ing. Civ. Fr. Oct.–Dec., '21.

Idées Générales et Pratiques pour l'Etablissement d'un Avant-Project de Station Marémotice avec Usine Régulatrice.* (General and Practical Points for the Establishment of an Experimental Tide-Power Station with an Auxiliary Plant.)* M. Bare. Ann. P. et C. Nov.-Dec. '21.

Technisch-wirtschaftliche Betrachtungen zum Wasserkraftwerksbau in Nordamerika. (Technical and Economic Considerations on the Construction of Water Power Plants in North America.) Schw. Bauz. Serial beginning Mar. 4, '22.

Die Einführung der elektrischen Zugförderung auf den österreichischen Staatsbahnen und der Ausbau der österreichischen Wasserkräfte.* (The Introduction of Electric Traction on the Austrian State Railways and the Development of Austrian Water Power.) R. Seifert. Z. d. Bauver. Serial beginning Mar. 11, '22.

Energievernichter für Hochdruckwasserkräfte.* (Energy Neutralizer for High Pressure Water Power.) K. Imhof. Oest. Ing. Arch. Ver. Mar. 17, '22.

Die projektierten Silsersee-Bergeller Kraftwerke.* (The Projected Silsersee-Bergeller Power Plants.) Adolf Salis. Schw. Bauz. Apr. 1, '22.

c. Pneumatics

2. Physical Pneumatics (Flow of Gases, Waves, Air Resistance, Action of the Wind)

Der Windanfall.* (Wind Penetration—Influence of Wind on Heating and Ventilation of Buildings.) F. Zaruba. Gesund. Ing. Mar. 4, '22.

3. Industrial Pneumatics (Wind Mills, Transmissions by Compressed Air, Blowers, Compressors, Propulsive and Elevating Machinery)

Conveying and Elevating Machinery.* Gardiner Mitchell (From paper read before Inst. Mech. Engrs.) Dock & Harbour. Apr. '22.

Limited Installation Space Leads to Special Elevating Equipment.* M. W. Hibbard. Eng. N. R. Apr. 6, '22.

C. Materials of Construction and General Processes

a. Lime, Cement, Mortar, Concrete, Brick, Bitumen, Timber, Gravel, etc.

Cresoil.* R. G. Smith. Am. Wood Prs. Assoc. 1921.

A Theory on the Mechanism of the Protection of Wood by Preservatives.* Part 11. Ernest Bateman. Am. Wood Prs. Assoc. 1921.

Report of Committee No. 5-5-1.—Pressure Treatments. Am. Wood Prs. Assoc. 1921.
Wood Preservation as a Conservation Policy. Walter Buehler. Am. Wood Prs. Assoc. 1921.
Perforated Butt-Treated Poles. W. M. Leavitt. Am. Wood Prs. Assoc. 1921.
Service-Tests of Treated and Untreated Fence Posts.* J. D. MacLean. Am. Wood Prs. Assoc. 1921.
Experiments with Butt-Treated Poles in California.* P. R. Hicks. Am. Wood Prs. Assoc. 1921.
Creosoted Lumber in Connection with Farm and Ranch. E. A. Lindsley. Am. Wood Prs. Assoc. 1921.
Report of Committee No. 4—Preservatives.* Am. Wood Prs. Assoc. 1921.
Report of Committee No. 7-01—Economics. Am. Wood Prs. Assoc. 1921.
Results of Some Tests of the Effects of Zinc Chloride on the Strength of Wood.* T. R. C. Wilson and Ernest Bateman. Am. Wood Prs. Assoc. 1921.
The Effect of the Zinc Chloride Process of Preservation on the Strength of Structural Timber.* H. B. Luther. Am. Wood Prs. Assoc. 1921.
Treatment of Mine Timber. L. W. Conrad. Am. Wood Prs. Assoc. 1921.
20-"Year" Tests of Cement and Mortar Materials. Cem. Eng. Apr., '22.
Methods of Crushing Stone in Texas.* Cem. Eng. Apr. '22.
New Laboratory Abrasion Test for Concrete.* Cem. Eng. Apr. '22.
Action of Alkali Salt on Portland Cement Mortars.* Dalton G. Miller (From paper read before Minnesota Surveyors' and Engrs.' Soc.) Eng. & Contr. Apr. 12, '22.
Sur les Progrès Techniques et d'Exécution Réalisés dans la Reconstruction des Ouvrages d'Art du Nord et de l'Est par les Ingénieurs Civils Francais.* (On the Technical Progress and Work done in Reconstruction in the North and East by French Civil Engineers). G. Leinekugel Le Cocq. Soc. Ing. Civ. Fr. Oct.-Dec., '21.
Lehmbauweisen und Erfahrungen mit Lehmbauten in Sorau und Zepernick bei Berlin nebst allgemeinen Gesichtspunkten.* (Loam Construction Methods and Experiences with Loam Buildings in Sorau and Zepernick near Berlin, with General Remarks.) R. Sonntag. Z. d. Bauver. Mar. 4, '22.

b. Metals

Sur les Progrès Techniques et d'Exécution Réalisés dans la Reconstruction des Ouvrages d'Art du Nord et de l'Est par les Ingénieurs Civils Francais.* (On the Technical Progress and Work done in Reconstruction in the North and East by French Civil Engineers). G. Leinekugel Le Cocq. Soc. Ing. Civ. Fr. Oct.-Dec., '21.

c. Preservation and Use of Materials. Painting, Waterproofing

How Membrane Waterproofing Is Laid.* A. S. Harrison. Ry. Main. Engr. Apr., '22.

f. Rock Excavation. Mining. Rock Removal

Use of Explosives in Production of Crushed Stone. S. R. Russell. Eng. & Contr., Apr. 19, '22.
Druckluft-Bohrmaschinen und -Hammer im Bergbau und in den Verwandten Betrieben.* (Compressed Air Drills and Hammers in Mining and Allied Operations.) R. Goetz. Ver. deu. Ing. Serial beginning Mar. 18, '22.

g. Execution of Works. Specifications

2. Of Concrete
Concrete Stock-Watering Tanks.* Cem. Eng. Apr., '22.
Experiences with Thin Concrete Slabs. John V. Shaefer. Cem. Eng. Apr., '22.
3. Of Wood
History and Growth of the Treated Wooden Silo. Am. Wood Prs. Assoc. 1921.
5. Of Reinforced Concrete
Eisenkonstruktionen zur Verstarkung von Eisenbetonbalken.* (Iron Framing for Strengthening Reinforced Concrete Beams.) Luitpold R. von Teng. Eisenbau Mar., '22.

h. Foundations

Die Pfeilerbewegungen der Eisenbahnbrücke über den Rhein bei Eglisau und die Massnahmen zur Sicherung des Bauwerkes.* (The Movements of the Piers of the Railroad Bridge over the Rhine at Eglisau and the Steps Taken to Make the Structure Safe.) E. Münster Schw. Bauz. Mar. 18, '22.
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PAPERS AND DISCUSSIONS

LOCOMOTIVE LOADINGS FOR RAILWAY BRIDGES

By D. B. Steinman,* M. Am. Soc. C. E.

Synopsis

For some time bridge engineers have recognized that the Cooper system of loading has ceased to provide a correct specification for the design of railway bridges, as it does not properly represent modern locomotive loadings. The specifying of different weights of Cooper engines for different lengths of span or for different members of the same span (as has been done) is, at best, a makeshift solution of the problem, and only serves to emphasize the need of a more consistent loading specification. In the successive attempts to keep pace with the continuous increase in railway loadings, the Cooper loading has been "strained beyond its elastic limit."

This paper presents a new loading system based on a study of the stress-producing effects of modern heavy locomotives.

The basic idea was to establish the maximum stresses producible at all sections of all spans by the heaviest existing locomotive loadings. The composite results showed a variation in equivalent Cooper ratings ranging from E-75 for the shorter spans to E-60 for the longer ones.

As the composite of the heaviest existing locomotive loadings is the best index of the directions in which the present average locomotive loadings may be expected to increase, it may fairly be taken as a standard or norm to which any new loading diagram proposed for the design of railway bridges ought to conform. The next step, therefore, was to devise a loading diagram or formula conforming as closely as practicable to this composite standard or norm. This paper offers three alternative solutions of this problem:

1.—A conventional wheel-load diagram, representing a locomotive of the Mallet type.

2.—A simplified loading diagram, consisting of a uniform load with three excess concentrations.

Note.—Written discussion will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

* Cons. Engr., New York City.

3.—A simple loading formula, giving directly the equivalent uniform load for any section of any span.

Each of these three alternative solutions has its distinctive advantages. The first represents the least departure from present methods, involving merely the substitution of a new and simpler wheel-load diagram for the one now in use.

The second solution offers a greatly simplified loading, which can be used expeditiously without tables or charts.

The third solution is the most scientific in principle and most convenient in application; tables, diagrams, and charts become endowed with simplicity and regularity; or, if tables and charts are not at hand, any maximum stress can be found by a simple operation on the ordinary slide-rule.

To expedite the application of the three proposed loading specifications, tables, charts, and isogonic diagrams of equivalent uniform loads are presented. Shear and moment graphs are also given, to show how closely the three proposed loadings conform to the composite standard for span lengths from 10 to 1 000 ft.

For each proposed loading system, the intensity corresponding to the composite standard is designated as Loading M-60. This loading can be increased or reduced in fixed ratios in the same manner as the Cooper system of loading. A rating chart and rating tables, included in the paper, permit quick comparison or conversion of E and M ratings for any member of any span.

Loading M-60 will give stresses for all spans very close to the maximum stresses producible by the heaviest existing locomotive loadings. It is about equivalent to Cooper's E-75 for short spans and to Cooper's E-60 for very long spans.

The adoption of Loading M-60 as a future loading specification instead of E-60 will insure that the short spans are strong enough for the heaviest locomotives and trains, without penalizing the longer spans with a 25% waste of metal.

The object of this paper is to direct attention to the inadequacy of the Cooper system to represent properly modern railway loadings; to submit, for the consideration of the Engineering Profession, three alternative forms of a new loading system based on the stress-producing effects of modern locomotives; and to secure, through discussion, a consensus of opinion as to which of the three proposed forms should be recommended as a future loading specification.

Introduction

The Cooper system of loading was introduced into American bridge practice about 30 years ago. At that time, the heaviest loads to be provided for were properly represented by Cooper's E-40 loading, consisting of two consolidation locomotives with 40 000 lb. on each driver axle, followed by a uniform train load of 4 000 lb. per lin. ft.

Since then there has been a rapid and continuous augmentation of locomotive and train weights. To provide for this increase, the original Cooper's E-40 loading was raised in successive specifications to the present values of E-60 and E-70 by applying fixed multiplying factors to the original loading diagram. This procedure could be applied indefinitely, without error, if the governing locomotive types and wheel spacings remained unchanged, and if the uniform train loads increased in the same proportion as the axle concentrations.

However, the old consolidation locomotive has been superseded by new types of engines having different wheel groupings and weight distributions. The wheel diagrams of such modern locomotive types as the Mikado, Mallet, or Santa Fé, bear little resemblance to Cooper's engine diagram. Moreover, since the days of the E-40 loading, the axle concentrations have increased 100%, whereas the weight of train per linear foot has increased barely 50 per cent. It should be obvious, from these considerations, that a limit has been reached in the proportionate stretching of the old Cooper engine loading to make it fit modern loading conditions, and that the time has come to make a fresh start, with a system based on the existing locomotive and train loads.

Besides minor anomalies, the most serious indictment against the Cooper system is that bridges of uniform strength for present-day traffic cannot be obtained except by specifying different classes of the Cooper loading for different lengths of span and for different members of the same span. The maximum equivalent Cooper rating of the heaviest existing locomotives varies from E-75 for short spans to E-60 for long spans.

For the New York Central Lines, provision in part is made for this variation by specifying Cooper's E-70 for spans up to 200 ft. and E-65 for spans of more than 200 ft. This, however, does not provide for variations within a structure of given span.

In strengthening the Niagara Railway Arch Bridge, C. E. Fowler, M. Am. Soc. C. E., adopted E-70 for the floor system of the 550-ft. span; E-60 for the truss members of the same span; and E-70 for the truss members of the 115-ft. approach spans.

Such hybrid loading specifications, necessitated by the lack of correspondence between the Cooper system and modern train loads, have obvious disadvantages and are, at best, a makeshift solution of the problem. They serve only to emphasize the need of a new loading specification that will be more consistent with present-day traffic.

The Cooper loading does not correspond to modern locomotives, and its retention as a standard for design is unscientific. Its use produces designs that are unbalanced for present-day loadings. For instance, the Pennsylvania Railroad N1S locomotives are equivalent to Cooper's E-55 for some bridge members and to E-75 for others, a range of variation of 37 per cent. The Erie 2-10-2 locomotives are equivalent to Cooper's E-53 for some bridge members and to E-70 for others, a range of variation of 32 per cent. Other locomotives, compared by the writer, gave similar ranges of variation. In other words, structures designed for the arbitrary Cooper loading will not be

of uniform strength for a given modern locomotive; some of the members in a span will be defective in strength in comparison with others, and some of the spans in a line will be disproportionately weak in comparison with others; and this difference in strength may amount to as much as 30 or 40 per cent.

An argument advanced for retaining the Cooper loading is that it affords a convenient standard for rating bridges; but the writer maintains that a standard that has become warped to such an extent as to yield results that fail to harmonize by 30 to 40%, has outlived its usefulness.

A new loading, in the form of a diagram, formula, or chart, should be developed for future specifications. This loading should satisfy the following requirements:

1.—It should give results that harmonize closely with the stresses producible by modern heavy locomotives.

2.—It should be heavy enough to provide for the probable future increase in loading during the desired life of the structure. Accordingly, it should be from 25 to 50% heavier than the average present loading (supposed to be represented by E-60).

3.—It should be presented in such form as will yield maximum facility of application and will discourage meaningless refinement of computation.

The foregoing considerations have prompted and guided the investigations embodied in this paper.

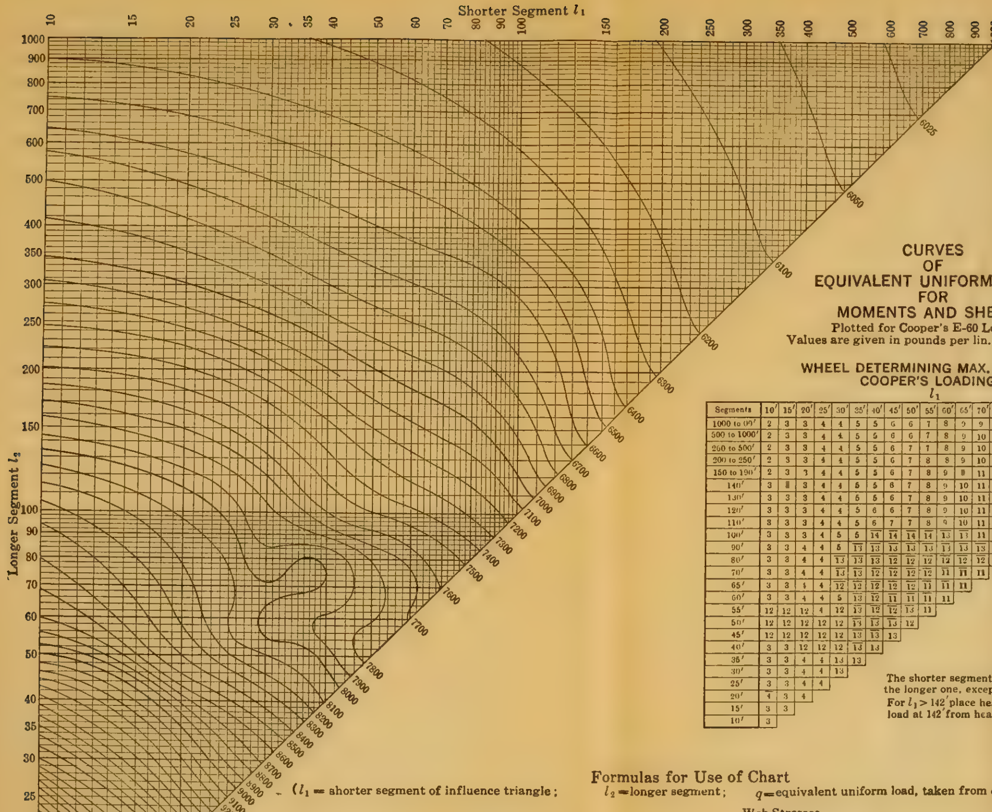
Composite of Heaviest Existing Locomotives

The first step toward establishing a new standard loading was to make an analysis of the stress-producing effects of the heaviest existing locomotives.

The most scientific way of studying, recording, and comparing the stress-producing characteristics of any specified loadings for all sections of all spans is on the basis of equivalent uniform loads. The equivalent uniform load for any section of any span represents the stress-producing value of a given loading, divested of all dimensional factors. Such a system of equivalent uniform loads was first published by the writer as a device for expediting the calculation of stresses for Cooper's loading. (See Plate XI.) The system is based on the principle that the equivalent uniform load for any stress depends only on the horizontal lengths, l_1 and l_2, of the two segments of the influence triangle for that stress. It is merely necessary to multiply this equivalent uniform load (taken from a table or chart) by a simple dimensional factor to obtain the maximum value of any stress.

Accordingly, the writer determined the equivalent uniform loads for the seven heaviest existing locomotives. The results are tabulated in Plate XII. The locomotives included in this analysis and comparison are the following:

(1) The Erie Railroad Class P1 (2-8-8-8-2).
(2) The Virginian Railway (2-10-10-2).
(3) Two Pennsylvania Railroad N1S engines (2-10-2).
(4) Two Erie engines (2-10-2).
(5) The Virginian Railway (2-8-8-2).
(6) The U. S. Standard (2-8-8-2) B.
(7) The Lake Shore and Michigan Southern Mallet (0-8-8-0).



CURVES OF EQUIVALENT UNIFORM LOADS FOR MOMENTS AND SHEARS

Plotted for Cooper's E-60 Loading
Values are given in pounds per lin. ft. per Track

WHEEL DETERMINING MAX. MOMENT COOPER'S LOADINGS

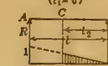
l_1

Segments	10′	15′	20′	25′	30′	35′	40′	45′	50′	55′	60′	65′	70′	80′	90′	100′	110′	120′	130′	140′
1000 to ∞′	2	3	3	4	4	5	5	6	6	7	8	9	9	11	12	13	14	15	17	19
500 to 1000′	2	3	3	4	4	5	5	6	6	7	8	9	10	11	12	13	14	15	17	18
250 to 500′	2	3	3	4	4	5	5	6	7	7	8	9	10	11	12	13	14	15	17	18
200 to 250′	2	3	3	4	4	5	5	6	7	8	8	9	10	11	12	13	14	15	17	18
150 to 190′	2	3	3	4	4	5	5	6	7	8	9	[illegible]	11	12	12	13	14	15	17	18
140′	3	[illegible]	3	4	4	5	5	6	7	8	9	10	11	12	12	13	14	15	17	[illegible]
130′	3	3	3	4	4	5	5	6	7	8	9	10	11	12	12	13	14	16	17	
120′	3	3	3	4	4	5	6	6	7	8	9	10	11	12	13	13	14	15		
110′	3	3	3	4	4	5	6	7	7	8	9	10	11	12	13	13	14			
100′	3	3	3	4	5	5	$\overline{14}$	$\overline{14}$	$\overline{14}$	$\overline{14}$	$\overline{13}$	$\overline{13}$	11	12	13	13				
90′	3	3	4	4	5	$\overline{13}$	$\overline{13}$	$\overline{13}$	$\overline{13}$	$\overline{13}$	$\overline{13}$	$\overline{13}$	$\overline{13}$	12	13					
80′	3	3	4	4	$\overline{13}$	$\overline{13}$	$\overline{13}$	$\overline{12}$	$\overline{12}$	$\overline{12}$	$\overline{12}$	$\overline{12}$	$\overline{12}$	12						
70′	3	3	4	4	$\overline{13}$	$\overline{13}$	$\overline{12}$	$\overline{12}$	$\overline{12}$	$\overline{12}$	$\overline{11}$	$\overline{11}$	11							
65′	3	3	4	4	$\overline{12}$	$\overline{12}$	$\overline{12}$	$\overline{12}$	$\overline{12}$	$\overline{11}$	$\overline{11}$	11								
60′	3	3	4	4	5	$\overline{13}$	$\overline{12}$	$\overline{11}$	$\overline{11}$	$\overline{11}$	11									
55′	12	12	12	4	12	$\overline{13}$	$\overline{12}$	$\overline{12}$	$\overline{13}$	11										
50′	12	12	12	12	12	$\overline{13}$	$\overline{13}$	$\overline{13}$	12											
45′	12	12	12	12	12	$\overline{13}$	$\overline{13}$	13												
40′	3	3	12	12	12	$\overline{13}$	13													
35′	3	3	4	4	13	13														
30′	3	3	4	4	13															
25′	3	3	4	4																
20′	$\overline{4}$	3	4																	
15′	3	3																		
10′	3																			

The shorter segment is ahead followed by the longer one, except wheel is overlined. For $l_1 > 142'$ place head of uniform train load at 142′ from head of span.

Equivalent Uniform Loads for Shears and Reactions

$(l_1 = 0)$



Max. Shear at C
* $S = \frac{1}{2} q\, l \cdot \frac{l_2}{l}$
Max. Reaction at A
$(l_2 = l)$
$R = \frac{1}{2} q l$

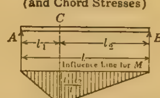
l_2	q
1000	6418
975	6429
950	6440
925	6451
900	6463
875	6476
850	6490
825	6504
800	6519
775	6535
750	6552
725	6571
700	6591
675	6612
650	6634
625	6658
600	6683
575	6711
550	6741
525	6775
500	6812
475	6852
450	6896
425	6945
400	7000
375	7060
350	7130
325	7205
300	7295
275	7400
250	7520
225	7660
200	7830
175	8035
[illegible]	8185
150	8300
140	8420
130	8540
120	8680
110	8840
100	9000
95	9060
90	9140
85	9230
80	9315
75	9410
70	9470
65	9600
60	9800
55	10 100
50	10 450
45	10 900
40	11 310
35	11 830
30	12 650
25	13 625
20	15 000
15	16 000
10	18 000
5	24 000

* Note:
In the above formula for S, the effect of wheel (1) is neglected.
To correct this, subtract $30\,000\left(1-\frac{l_2+[illegible]}{l}\right)$ from the above value of S

Formulas for Use of Chart

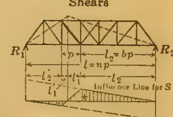
(l_1 = shorter segment of influence triangle; l_2 = longer segment; q = equivalent uniform load, taken from chart for l_1 and l_2)

Bending Moments (and Chord Stresses)



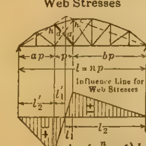
Max. Moment at C in span $\overline{AB}$
$M = \frac{1}{2} q\, l_1 l_2$
(l_1 and l_2 = the segments of the span)

Shears



Max. Shear in Truss Panel
$S = \frac{1}{2} q\, l_1 l_2 \div p$
$\left(l_1 = \frac{l_2}{n-1}, \quad l_2 = bp\right)$

Web Stresses

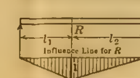


$l_1 = \left(\frac{n}{ar+b} - 1\right) \cdot l_2, \quad r = \frac{h'}{h}$

For Member shown full:
Max. + Web. Stress $= \frac{1}{2} q\, l_1 l_2 \cdot \frac{\sec\alpha}{rp}$
Max. − Web. Stress $= \frac{1}{2} q\, l_1' l_2' \cdot \frac{\sec\alpha}{p}$

For Member shown dotted:
Max. − Web. Stress $= \frac{1}{2} q\, l_1 l_2 \cdot \frac{\sec\alpha'}{p}$
Max. + Web. Stress $= \frac{1}{2} q\, l_1' l_2' \cdot \frac{r \sec\alpha'}{p}$

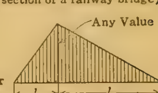
Floorbeam Reactions Intermediate Pier Reactions



Max. Intermediate Reaction
$R = \frac{1}{2} q\,(l_1 + l_2)$
(l_1 and l_2 = the two adjoining spans.)

TABLE OF EQUIVALENT UNIFORM LOADS FOR HEAVIEST LOCOMOTIVE LOADINGS

(For calculating maximum possible stress in any member or section of a railway bridge)



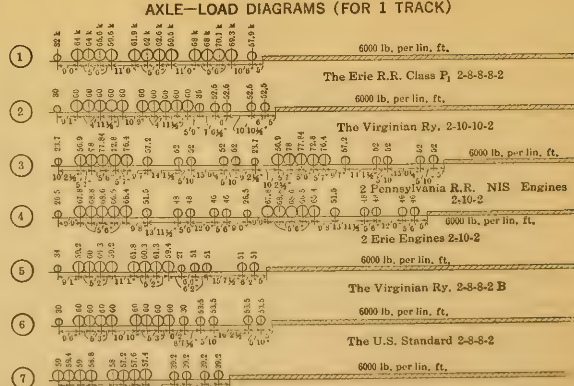
l_1 = Shorter segment of Influence Triangle
l_2 = Longer segment of Influence Triangle
q = Equivalent Uniform Load, taken from Table for the values of l_1 and l_2

This table can be used for finding maximum bending moments, shears, chord stresses, web stresses, counter stresses, end reactions, etc.

For Maximum Bending Moment at any section of any span
$$M = \tfrac{1}{2} \cdot q \cdot l_1 \cdot l_2$$

	0	10	20	30	40	50	60	70	80	90	100	120	140	160	180	200	220	240	260	280	300	400	500	600	700	800	900	1000
1000	6600 6576 6502 6415 6368 6354 6293	6540 6500 6460 6320 6300 6300 6220	6500 6480 6440 6340 6290 6290 6220	6480 6460 6370 6320 6280 6240 6150	6440 6140 6360 6270 6230 6220 6140	6420 6400 6340 6260 6220 6200 6110	6400 6380 6200 6220 6210 6180 6100	6400 6360 6280 6190 6180 6170 6080	6380 6350 6250 6180 6140 6160 6050	6360 6320 6240 6160 6120 6140 6040	6340 6300 6230 6170 6100 6120 6038	6300 6260 6220 6160 6080 6090 6034	6220 6200 6210 6140 6078 6080 6028	6214 6160 6200 6110 6066 6070 6024	6186 6140 6130 6100 6058 6060 6022	6166 6130 6126 6090 6052 6055 6018	6148 6120 6120 6080 6046 6050 6017	6134 6110 6110 6080 6042 6045 6016	6122 6100 6100 6075 6038 6040 6014	6110 6090 6090 6070 6034 6040 6013	6102 6080 6080 6060 6032 6035 6012	6070 6060 6060 6050 6022 6030 6008	6052 6050 6050 6040 6018 6025 6006	6042 6040 6040 6030 6012 6020 6005	6034 6020 6030 6025 6010 6015 6004	6028 6020 6025 6020 6008 6010 6004	6024 6020 6020 6015 6007 6005 6003	6020 6010 6010 6010 6006 6004 6002
900	6665 6637 6556 6460 6409 6404 6325	6600 6560 6500 6390 6380 6350 6250	6560 6540 6480 6380 6320 6340 6240	6540 6500 6420 6320 6300 6280 6160	6500 6480 6400 6300 6260 6260 6140	6480 6460 6360 6260 6250 6220 6130	6460 6440 6320 6240 6240 6200 6120	6440 6400 6300 6210 6180 6180 6100	6420 6380 6260 6200 6170 6170 6070	6400 6360 6280 6190 6160 6140 6060	6380 6300 6240 6200 6120 6120 6040	6340 6280 6260 6190 6100 6080 6036	6240 6220 6240 6160 6084 6070 6030	6234 6180 6220 6130 6072 6070 6020	6204 6160 6160 6120 6064 6065 6024	6180 6140 6150 6110 6056 6060 6020	6162 6130 6140 6100 6050 6055 6018	6146 6120 6130 6090 6046 6050 6016	6132 6100 6120 6080 6040 6045 6015	6120 6100 6110 6070 6038 6040 6014	6110 6080 6100 6060 6034 6035 6012	6076 6060 6060 6050 6024 6030 6008	6056 6040 6050 6040 6018 6025 6007	6044 6040 6040 6030 6014 6020 6006	6036 6030 6030 6025 6011 6015 6005	6030 6020 6020 6020 6010 6010 6004	6024 6010 6015 6015 6008 6000 6002	
800	6744 6716 6622 6514 6459 6453 6366	6680 6640 6560 6440 6420 6400 6290	6640 6580 6540 6400 6360 6380 6280	6620 6560 6470 6360 6320 6330 6130	6560 6540 6460 6320 6200 6320 6170	6540 6500 6420 6300 6280 6250 6160	6520 6480 6360 6240 6240 6240 6120	6500 6440 6320 6220 6210 6230 6100	6480 6420 6280 6220 6200 6200 6080	6440 6380 6300 6210 6180 6160 6070	6400 6320 6260 6205 6140 6140 6060	6360 6280 6280 6200 6120 6110 6040	6300 6240 6250 6190 6094 6100 6034	6258 6200 6240 6150 6080 6090 6030	6224 6180 6180 6140 6070 6080 6026	6198 6160 6160 6120 6062 6070 6022	6176 6140 6150 6110 6054 6065 6020	6158 6120 6140 6100 6050 6060 6018	6144 6110 6130 6090 6044 6055 6016	6132 6100 6120 6080 6040 6045 6015	6120 6090 6100 6060 6038 6040 6014	6082 6080 6070 6050 6026 6030 6010	6060 6050 6060 6040 6018 6025 6007	6048 6040 6050 6030 6014 6020 6006	6038 6030 6040 6020 6012 6015 6005	6030 6020 6020 6015 6010 6010 6004		
700	6846 6814 6706 6584 6524 6517 6418	6760 6720 6620 6480 6420 6440 6320	6720 6660 6580 6460 6400 6410 6300	6660 6640 6560 6420 6360 6370 6200	6620 6620 6500 6360 6340 6360 6190	6580 6560 6440 6320 6320 6280 6180	6560 6530 6420 6280 6280 6270 6130	6540 6520 6340 6250 6240 6240 6120	6500 6460 6310 6240 6200 6200 6080	6480 6420 6320 6230 6180 6170 6070	6460 6380 6310 6220 6160 6160 6060	6400 6320 6300 6250 6120 6110 6046	6320 6260 6280 6220 6104 6100 6038	6288 6240 6270 6170 6090 6090 6032	6250 6200 6180 6160 6078 6085 6028	6220 6180 6170 6180 6068 6080 6024	6196 6150 6160 6120 6060 6070 6022	6176 6140 6150 6110 6054 6065 6020	6160 6130 6140 6100 6050 6060 6018	6144 6120 6130 6090 6044 6055 6016	6132 6100 6120 6080 6042 6040 6014	6090 6080 6070 6060 6028 6030 6010	6066 6060 6060 6040 6020 6025 6008	6050 6050 6050 6030 6016 6020 6006	6040 6040 6040 6020 6012 6015 6004			
600	6981 6942 6816 6676 6608 6601 6488	6860 6840 6700 6580 6500 6520 6380	6840 6770 6680 6520 6490 6480 6320	6800 6760 6640 6480 6440 6420 6260	6760 6720 6560 6440 6400 6380 6210	6700 6640 6500 6390 6340 6320 6200	6680 6520 6480 6320 6340 6300 6150	6640 6600 6400 6290 6260 6260 6140	6600 6520 6380 6280 6240 6240 6100	6560 6500 6370 6270 6180 6200 6080	6500 6440 6360 6270 6180 6160 6060	6440 6360 6340 6280 6140 6130 6052	6380 6300 6320 6240 6120 6120 6044	6326 6260 6300 6190 6102 6110 6036	6282 6240 6200 6180 6088 6100 6032	6248 6200 6190 6140 6078 6090 6028	6220 6170 6180 6130 6068 6080 6024	6196 6160 6170 6120 6062 6070 6022	6178 6140 6160 6110 6056 6065 6020	6162 6120 6140 6100 6050 6060 6018	6146 6100 6120 6080 6046 6050 6016	6100 6080 6080 6060 6030 6040 6012	6072 6060 6060 6050 6022 6030 6008	6056 6050 6040 6040 6018 6020 6006				
500	7160 7122 6964 6803 6726 6719 6584	7040 6980 6860 6640 6660 6600 6440	6980 6940 6780 6620 6560 6540 6400	6920 6880 6720 6580 6520 6480 6320	6860 6840 6640 6500 6460 6460 6260	6820 6760 6600 6440 6440 6390 6220	6800 6720 6520 6360 6400 6380 6180	6740 6680 6460 6350 6320 6320 6160	6700 6640 6420 6340 6300 6280 6120	6660 6600 6410 6310 6260 6240 6100	6600 6540 6400 6310 6200 6220 6065	6540 6420 6390 6320 6140 6160 6060	6449 6360 6380 6280 6138 6140 6048	6376 6300 6340 6210 6116 6110 6042	6324 6260 6240 6200 6100 6100 6036	6282 6220 6220 6160 6088 6090 6032	6250 6200 6210 6140 6078 6060 6028	6224 6160 6200 6130 6070 6070 6026	6200 6160 6180 6120 6062 6065 6022	6182 6140 6160 6110 6056 6060 6020	6166 6120 6140 6100 6052 6050 6018	6110 6080 6080 6060 6034 6040 6012	6080 6060 6060 6050 6024 6020 6005					
400	7423 7380 7184 6988 6901 6894 6729	7240 7220 7040 6820 6740 6720 6560	7200 7160 6980 6760 6700 6660 6500	7120 7120 6880 6680 6640 6520 6400	7060 7040 6800 6600 6580 6520 6320	6980 6920 6720 6540 6520 6480 6300	6940 6900 6640 6480 6480 6460 6240	6920 6800 6600 6420 6400 6400 6200	6820 6760 6520 6390 6340 6340 6120	6800 6720 6500 6385 6280 6300 6100	6760 6640 6470 6380 6260 6260 6100	6620 6500 6450 6370 6180 6180 6072	6500 6410 6440 6320 6164 6160 6060	6442 6360 6400 6280 6130 6130 6050	6380 6300 6320 6240 6108 6120 6042	6330 6260 6280 6200 6104 6100 6038	6290 6240 6240 6160 6090 6090 6032	6258 6200 6220 6140 6080 6085 6030	6232 6180 6200 6130 6072 6080 6026	6208 6160 6180 6120 6064 6075 6024	6188 6140 6160 6100 6058 6040 6022	6124 6100 6100 6080 6038 6035 6014						
300	7842 7800 7523 7282 7188 7180 6970	7600 7560 7320 7040 6920 6960 6760	7520 7480 7200 6960 6910 6880 6640	7440 7400 7140 6880 6820 6760 6540	7340 7260 6980 6760 6710 6720 6460	7280 7180 6890 6680 6660 6620 6380	7200 7120 6780 6560 6600 6580 6320	7140 7020 6700 6500 6520 6500 6260	7040 6960 6640 6490 6460 6420 6160	7000 6880 6620 6480 6360 6360 6160	6900 6760 6610 6460 6320 6320 6120	6720 6660 6620 6480 6220 6240 6090	6620 6540 6560 6420 6200 6200 6072	6540 6440 6480 6360 6168 6160 6060	6460 6360 6420 6250 6142 6140 6052	6396 6320 6320 6240 6124 6120 6044	6346 6280 6280 6200 6108 6100 6040	6306 6240 6260 6180 6096 6090 6084	6272 6220 6240 6160 6084 6080 6030	6244 6200 6200 6140 6076 6070 6028	6220 6180 6180 6120 6068 6060 6024							
280	7958 7915 7615 7362 7269 7261 7037	7740 7700 7380 7120 7000 7020 6820	7640 7600 7260 7020 6940 6940 6680	7520 7500 7180 6920 6900 6840 6580	7400 7320 7060 6840 6800 6760 6480	7340 7240 6940 6680 6740 6660 6400	7260 7180 6820 6580 6640 6620 6340	7180 7080 6720 6530 6540 6540 6280	7100 7000 6680 6520 6500 6460 6200	7040 6900 6640 6490 6400 6380 6160	6960 6840 6620 6480 6320 6320 6140	6840 6680 6640 6470 6220 6240 6094	6660 6560 6580 6440 6210 6200 6076	6564 6460 6520 6360 6176 6170 6064	6480 6380 6420 6280 6148 6160 6054	6412 6320 6360 6260 6128 6120 6046	6360 6280 6300 6200 6112 6110 6040	6318 6260 6260 6190 6098 6100 6036	6282 6220 6240 6180 6088 6090 6032	6254 6200 6220 6140 6078 6080 6028								
260	8086 8044 7716 7453 7361 7353 7118	7820 7800 7480 7180 7060 7080 6900	7720 7660 7340 7100 7040 7020 6760	7620 7580 7260 6960 6940 6900 6640	7520 7480 7100 6860 6840 6800 6500	7420 7320 6980 6740 6760 6700 6440	7340 7240 6840 6620 6660 6660 6360	7280 7140 6740 6560 6620 6580 6300	7160 7060 6720 6540 6520 6480 6220	7110 6950 6680 6530 6440 6420 6160	7040 6880 6640 6520 6340 6360 6140	6880 6700 6660 6510 6240 6260 6098	6700 6580 6600 6460 6220 6220 6080	6592 6480 6540 6360 6184 6180 6066	6500 6400 6440 6280 6156 6160 6056	6432 6340 6360 6260 6134 6130 6048	6376 6300 6320 6220 6110 6120 6042	6330 6260 6280 6190 6102 6110 6038	6294 6240 6260 6180 6090 6100 6034									
240	8228 8195 7838 7554 7469 7461 7207	7940 7920 7560 7240 7140 7160 6960	7820 7780 7440 7160 7100 7100 6800	7700 7640 7320 7040 7000 6960 6680	7600 7560 7160 6920 6860 6880 6560	7500 7400 7040 6760 6800 6740 6480	7440 7320 6900 6640 6740 6700 6380	7340 7240 6780 6600 6640 6600 6320	7240 7120 6760 6580 6560 6520 6240	7200 7020 6740 6570 6480 6440 6180	7080 6920 6710 6560 6360 6380 6160	6900 6760 6720 6550 6260 6280 6104	6740 6620 6640 6480 6232 6220 6084	6620 6500 6580 6380 6192 6180 6070	6524 6420 6460 6290 6164 6160 6060	6450 6360 6400 6280 6140 6140 6050	6392 6320 6320 6220 6122 6130 6044	6344 6280 6280 6200 6108 6120 6088										
220	8397 8367 7971 7673 7597 7588 7315	8140 8060 7660 7340 7240 7280 7020	7960 7920 7520 7240 7200 7160 6880	7820 7800 7420 7100 7080 7000 6740	7700 7640 7220 6980 6940 6900 6620	7600 7500 7100 6800 6850 6800 6520	7520 7440 6960 6660 6800 6740 6440	7440 7320 6840 6640 6700 6640 6340	7380 7220 6800 6600 6600 6560 6240	7240 7100 6780 6620 6500 6480 6200	7140 6960 6720 6600 6400 6400 6160	6980 6800 6760 6580 6300 6300 6110	6800 6640 6680 6500 6244 6240 6090	6652 6520 6620 6400 6202 6200 6074	6550 6440 6480 6320 6172 6160 6062	6472 6360 6470 6280 6146 6140 6054	6430 6320 6340 6240 6128 6120 6046											
200	8590 8570 8120 7810 7740 7736 7448	8240 8220 7780 7420 7340 7400 7140	8100 8080 7620 7320 7280 7280 6960	7960 7960 7480 7180 7160 7160 6780	7800 7760 7320 7040 7040 7000 6660	7720 7600 7140 6880 6940 6880 6580	7640 7520 6960 6700 6860 6820 6460	7540 7460 6850 6660 6760 6720 6380	7440 7300 6810 6620 6640 6560 6260	7340 7180 6800 6640 6520 6500 6200	7220 7040 6790 6630 6440 6420 6160	7040 6840 6810 6600 6320 6340 6116	6840 6720 6720 6540 6260 6260 6094	6688 6560 6640 6440 6214 6220 6078	6580 6480 6520 6340 6180 6180 6066	6496 6380 6420 6280 6154 6160 6056												
180	8815 8808 8297 7974 7916 7910 7604	8400 8400 7940 7500 7420 7520 7260	8240 8240 7740 7420 7400 7360 7040	8100 8080 7580 7260 7280 7240 6880	7920 7920 7380 7080 7100 7040 6700	7580 7720 7200 6940 7000 6960 6640	7720 7640 7120 6760 6920 6880 6500	7660 7480 6920 6720 6860 6760 6400	7540 7400 6850 6650 6700 6640 6280	7440 7260 6840 6640 6600 6620 6240	7300 7120 6840 6680 6480 6480 6180	7060 6920 6870 6680 6340 6360 6124	6880 6720 6760 6600 6276 6260 6100	6730 6580 6680 6480 6226 6220 6082	6612 6480 6580 6360 6190 6200 6070													
160	9076 9090 8400 8165 8135 8136 7801	8620 8640 8080 7680 7720 7680 7350	8420 8400 7860 7520 7580 7540 7200	8260 8260 7680 7360 7380 7360 6960	8100 8080 7480 7160 7240 7180 6800	8000 7900 7300 6980 7120 7060 6700	7900 7760 7100 6820 7000 6980 6560	7760 7600 7000 6740 6880 6800 6460	7660 7500 6920 6690 6760 6720 6300	7540 7360 6910 6700 6620 6580 6240	7400 7220 6900 6720 6500 6500 6200	7180 6960 6930 6710 6360 6380 6134	6960 6780 6880 6640 6294 6280 6106	6736 6640 6720 6500 6240 6240 6088														
140	9390 9440 8650 8300 8410 8415 8057	8840 8920 8220 7840 7940 7900 7580	8700 8700 8000 7660 7760 7700 7320	8480 8450 7800 7440 7540 7500 7080	8260 8260 7580 7260 7320 7300 6880	8160 8080 7360 7060 7240 7160 6760	8100 7960 7160 6880 7140 7020 6620	7900 7760 7020 6800 6880 6920 6480	7800 7640 6970 6770 6820 6780 6320	7640 7460 6960 6760 6680 6640 6240	7520 7300 6940 6780 6560 6540 6200	7260 7000 6960 6780 6380 6400 6144	7040 6840 6880 6680 6314 6300 6114															
120	9742 9860 8850 8500 8760 8780 8360	9160 9240 8380 7980 8200 8100 7820	8940 8980 8100 7760 7960 7900 7520	8720 8720 7880 7540 7740 7640 7240	8500 8500 7640 7320 7520 7440 7000	8380 8260 7400 7100 7360 7300 6880	8220 8140 7200 6960 7260 7200 6720	8040 7960 7040 6840 7080 7000 6560	7960 7780 7010 6800 6880 6860 6360	7820 7600 7000 6760 6740 6720 6300	7680 7460 7000 6850 6600 6580 6240	7360 7140 7080 6840 6420 6420 6166																
100	10192 10374 9040 8780 9230 9260 8852	9560 9660 8440 8020 8560 8500 8160	9280 9320 8100 7780 8240 8160 7780	8980 9040 7820 7560 7980 7880 7440	8740 8720 7580 7340 7760 7620 7200	8620 8560 7380 7120 7560 7500 7000	8460 8340 7180 6940 7380 7340 6820	8260 8180 6900 6800 7240 7180 6620	8140 7940 7050 6860 7040 6980 6440	8000 7740 7040 6880 6880 6800 6300	7840 7560 7140 6940 6660 6640 6260																	
90	10694 10600 10000 9100 9535 9570 9156	9740 9660 8660 8120 8760 8700 8400	9460 9500 8260 7820 8420 8320 7960	9140 9200 7900 7540 8120 8040 7560	8860 8920 7580 7360 7840 7760 7280	8800 8720 7300 7080 7700 7600 7120	8560 8500 7080 6930 7520 7440 6880	8380 8300 7040 6920 7300 7220 6660	8280 8100 7070 6960 7100 7040 6480	8120 7880 7080 6940 6900 6840 6340																		
80	10893 10940 10500 9500 10580 9900 9539	9960 10100 9060 8380 9020 8900 8640	9580 9700 8560 8040 8620 8500 8140	9320 9380 8120 7620 8280 8220 7740	9000 9040 7660 7360 7980 7880 7440	8900 8900 7360 7000 7840 7740 7240	8700 8640 7300 7000 7620 7540 6960	8500 8440 7100 6860 7400 7320 6700	8400 8200 7080 6920 7100 7100 6820																			
70	11102 11260 10950 9950 10600 10200 9950	10120 10360 9500 8780 9300 9180 8900	9780 9920 8900 8340 8840 8740 8420	9420 9580 8400 7700 8500 8360 7920	9140 9180 7760 7420 8160 8080 7580	9040 9060 7480 7060 7980 7880 7360	8840 8840 7100 6740 7760 7660 7080	8640 8600 6920 6820 7520 7420 6820																				
60	11395 11600 11300 10400 10800 10700 10500	10180 10540 10000 8900 9660 9540 9340	9720 10100 9260 8680 9140 9040 8700	9440 9740 8720 8160 8720 8620 8160	9300 9400 8200 7700 8420 8250 7800	9200 9240 7480 7240 8300 8060 7600	9000 9040 7480 6860 7920 7800 7200																					
50	12001 12230 12230 11600 11100 11000 11050	10420 10720 10720 9830 9660 9780 9740	9797 10240 9840 9120 9300 9240 9020	9654 9840 9300 8520 9000 8840 8460	9404 9500 8500 7940 8660 8560 8000	9328 9480 7920 7420 8420 8300 7720																						
40	12551 12500 13500 12800 11600 11500 11700	10768 10720 11520 10640 10040 9980 10200	10070 10350 10400 9620 9500 9420 9420	9650 10020 9620 8900 9160 8980 8720	9450 9900 8900 8320 8920 8800 8360																							
30	13677 13600 15460 14400 12800 12400 12500	11048 11000 12700 11680 10100 10040 10240	10168 10240 11400 10460 9600 9420 9600	9753 10040 10320 9600 9340 9180 8960																								
20	16263 15000 18400 16060 15000 14550 14900	12070 12060 13680 12700 10800 10760 10920	10591 10600 12330 11220 9500 9440 9620																									
10	20256 18144 23600 18360 18860 16400 16800	12188 12140 14580 14020 11800 11700 12040																										

AXLE—LOAD DIAGRAMS (FOR 1 TRACK)



Behind each of these locomotives is a uniform train load of 6 000 lb. per lin. ft., which fairly represents the heaviest continuous train loads. (An extra heavy coal car on the Virginian Railway weighs 5 940 lb. per ft. of track when loaded to capacity, and 6 380 lb. per ft. with 10% overload).

The table given on Plate XII covers a range of values of l_1 and l_2 extending from 10 to 1 000 ft. For each point in the table, there are recorded seven values of equivalent uniform loads corresponding, respectively, to the seven locomotives previously listed. The largest of the seven values in each block is indicated in bold-face type.

These maximum equivalent uniform loads, given in bold-face type on Plate XII, represent a composite of the heaviest existing loadings. A table of these maximum values would constitute in itself an adequate loading specification to insure the safe and balanced design of all spans for the heaviest present-day locomotives.

The seven locomotives are listed in the general order of their stress-producing effects. There are, however, variations from this order; each locomotive has low points in the table (Plate XII) where it is overlapped by one or more of the lighter locomotives. This fact constitutes an outstanding advantage of a composite loading, as it is free from arbitrary low points due to the individual peculiarities of a single locomotive.

It is found by inspection of the table (Plate XII) that Locomotive No. 1 produces maximum stresses for all points above an indicated zigzag line corresponding approximately to a span of 150 ft. Between this line and a lower zigzag line, corresponding to a span of about 60 ft., Locomotive No. 2 produces maximum stresses. For all shorter spans, Locomotive No. 3 is the governing load. Therefore, Locomotives Nos. 1, 2, and 3 are sufficient to cover the entire field of existing locomotives as far as maximum stress-producing effect is concerned. A composite of these three engines would give stresses greater than any known loading for any section or member of any span.

In order to present in graphic form the composite stress-producing characteristics of the heaviest locomotives, the maximum values of the equivalent uniform loads were next platted on a chart (Plate XIII). This diagram is of the same form as Plate XI for the Cooper loading, referred to previously. It possesses, however, striking advantages over the Cooper chart. The curves are more regular and the spacing is more even; the low points and kinks due to the idiosyncracies of the Cooper engine diagram are eliminated. The smoothness of the curves is an insurance against designs becoming unbalanced by future changes in locomotive wheel diagrams.

This chart (Plate XIII) does not represent any single known engine but, instead, it represents a maximum composite of all existing engines and train loads, including the heaviest types. No known loading can produce a greater stress in any member than is given by this chart. Surely this fact alone ought to commend the chart as a standard for future loading specifications.

This chart (Plate XIII) may be conceived as a plat of equivalent load curves, each enveloping the corresponding curves for all existing locomotives.

The author submits this chart (Plate XIII), or its tabular form, Plate XII, to the Profession as a standard or norm to which any new loading diagram proposed for the design of railway bridges ought to conform. If desired, this chart alone could be incorporated in bridge specifications as a simple and adequate prescription for all railway live load stresses. Bridges designed thereby would be safe, without waste, for the heaviest loadings thus far developed.

The loading, real or imaginary, represented by this chart (Plate XIII) will hereinafter be referred to as the "Composite Standard Loading", and will be designated by the class symbol, M-60.

Plate XIV presents a tabulation giving for each point the equivalent uniform load for the Composite Standard Loading and, also, the respective ratios thereto of the equivalent uniform loads for the seven heaviest existing locomotives.

This table (Plate XIV) is presented, primarily, to show how little the Composite Standard Loading would be changed by the omission of any one of the seven loadings entering into it. For instance, if Locomotive No. 1 were omitted, the maximum reduction of stress would be only 3.6%; if Locomotive No. 2 were eliminated, the maximum stress reduction would be only 3.9%; if Locomotive No. 3 were omitted, there would be no stress reduction, except for very short spans; if any or all of the remaining locomotives (Nos. 4 to 7, inclusive) were omitted, the Composite Standard Loading would be entirely unaffected.

As the omission of any of the heaviest locomotives effects so slight a reduction in the Composite Standard Loading, it is logical to expect that the addition of any new locomotive that may be developed in the near future will produce an equally slight augmentation in the Composite Standard Loading. In other words, the Composite Standard Loading provides for probable future development in load distribution as well as for present-day loading.

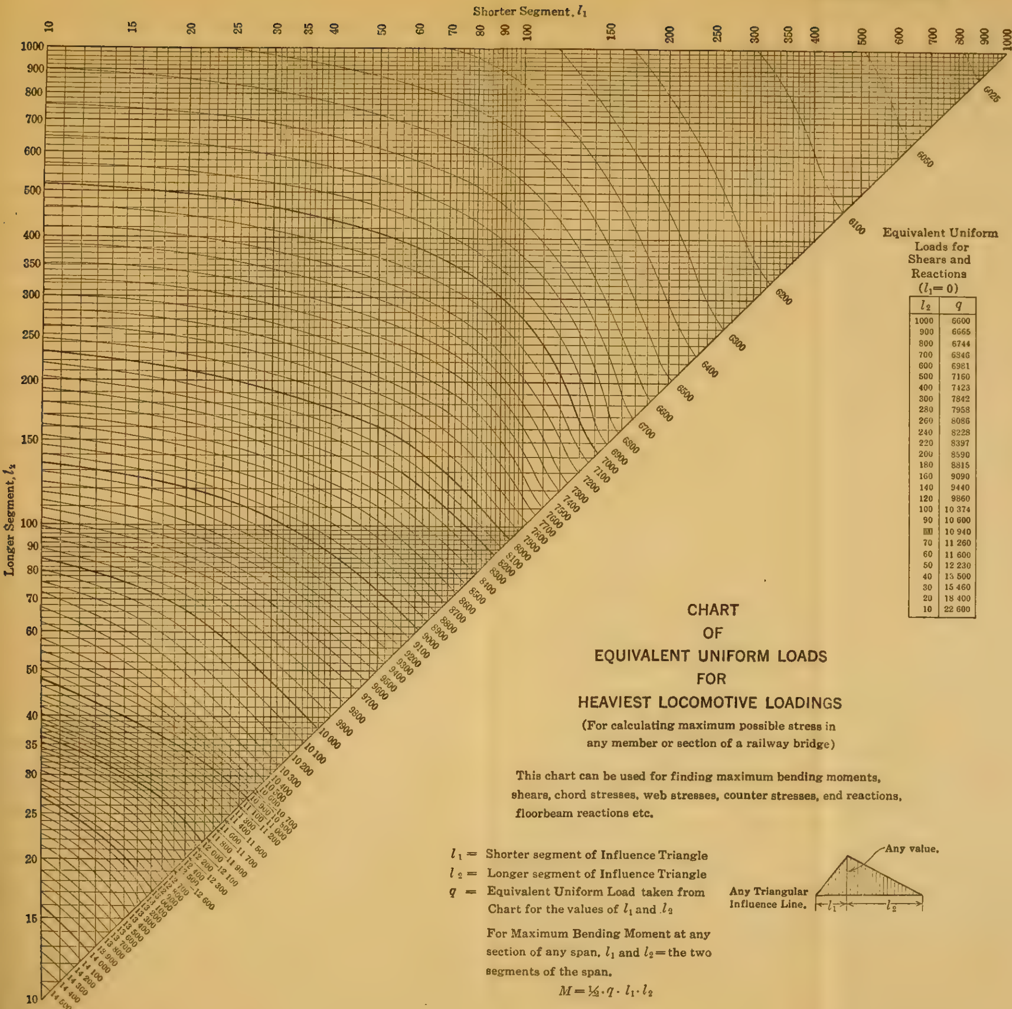
The tabulation of percentages in Plate XIV is also useful in comparing the stresses given by the Composite Standard Loading and those producible by any one of the heavy locomotives listed. For instance, if Locomotive No. 7 (the Lake Shore and Michigan Southern Mallet) is the heaviest locomotive on a line, and if the spans do not exceed 300 ft., the tabulation on Plate XIV shows that it will be sufficient to specify 90% of the Composite Standard Loading.

If the stresses for any bridge are calculated from the chart (Plate XIII) for the Composite Standard Loading, the percentages tabulated in Plate XIV can then be applied, if desired, to give the exact stresses producible by any specific heavy locomotive.

The tabulated percentages in Plate XIV can also be used to show the safety, under any proposed engine, of a structure designed for any other engine in the list. Other uses of this table (Plate XIV) will suggest themselves to the bridge engineer.

The table on Plate XV gives the equivalent uniform load (per track) for Cooper's E-60 loading for any section in any span and, also, the corresponding

PLATE XIII.
PAPERS, AM. SOC. C. E.
MAY, 1922.
STEINMAN ON
LOCOMOTIVE LOADINGS
FOR RAILWAY BRIDGES.



Equivalent Uniform Loads for Shears and Reactions ($l_1 = 0$)

l_2	q
1000	6600
900	6665
800	6744
700	6846
600	6981
500	7160
400	7423
300	7842
280	7958
260	8086
240	8228
220	8397
200	8590
180	8815
160	9090
140	9440
120	9860
100	10 374
90	10 600
[illegible]	10 940
70	11 260
60	11 600
50	12 230
40	13 500
30	15 460
20	18 400
10	22 600

CHART OF EQUIVALENT UNIFORM LOADS FOR HEAVIEST LOCOMOTIVE LOADINGS

(For calculating maximum possible stress in any member or section of a railway bridge)

This chart can be used for finding maximum bending moments, shears, chord stresses, web stresses, counter stresses, end reactions, floorbeam reactions etc.

l_1 = Shorter segment of Influence Triangle
l_2 = Longer segment of Influence Triangle
q = Equivalent Uniform Load taken from Chart for the values of l_1 and l_2

For Maximum Bending Moment at any section of any span, l_1 and l_2 = the two segments of the span.

$$M = \tfrac{1}{2} \cdot q \cdot l_1 \cdot l_2$$

TABLE OF MAXIMUM AND RELATIVE EQUIVALENT UNIFORM LOADS FOR HEAVIEST LOCOMOTIVE LOADINGS

	0	10	20	30	40	50	60	70	80	90	100	120	140	160	180	200	220	240	260	280	300	400	500	600	700	800	900	1000
1000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
900	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
800	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
700	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
600	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				
500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					
400	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]						
300	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]							
280	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								
260	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]									
240	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]										
220	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]											
200	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]												
180	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]													
160	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]														
140	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]															
120	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																
100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																	
90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																		
80	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																			
70	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																				
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50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																						
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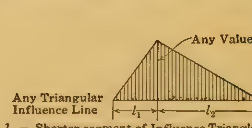
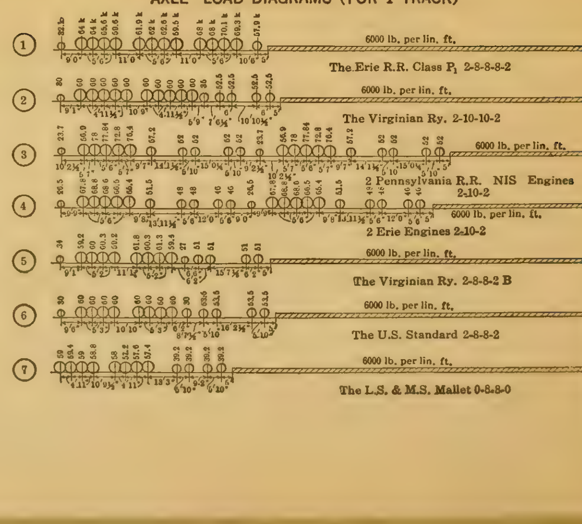


l_1 = Shorter segment of Influence Triangle
l_2 = Longer segment of Influence Triangle
q = Equivalent Uniform Load, taken from Table for the values of l_1 and l_2

This table can be used for finding maximum bending moments, shears, chord stresses, web stresses, counter stresses, end reactions, etc.

For Maximum Bending Moment at any section of any span
$M = \frac{1}{2} \cdot q \cdot l_1 \cdot l_2$

AXLE-LOAD DIAGRAMS (FOR 1 TRACK)



[illegible]

Cooper ratings for the seven heaviest locomotive loadings, in order to permit direct comparison or conversion of stresses.

Aside from the general purpose of this paper, this table (Plate XV) is useful for determining the overloading effects of any one of the heavy locomotives on a structure designed for a given Cooper loading.

The principal object in presenting this table (Plate XV), however, is to show the disparity between the Cooper loading and the heavy locomotives now in use. Table 1 shows the extreme variations in equivalent Cooper ratings for the seven locomotives investigated.

TABLE 1.—EQUIVALENT COOPER RATINGS OF SEVEN HEAVIEST EXISTING LOCOMOTIVE LOADINGS.

Loading.	Minimum rating.	Maximum rating.	Range of variation.
1	E-60.1	E-72.0	20%
2	E-60.0	E-73.5	22 "
3	E-54.8	E-75.0	37 "
4	E-52.7	E-69.3	32 "
5	E-56.1	E-68.2	22 "
6	E-54.7	E-66.2	21 "
7	E-52.3	E-65.0	24 "

This attempt to apply the Cooper system as a measuring standard for rating existing railway loadings reveals the difficulties that have arisen. The Cooper system and modern loadings have become incommensurable. A given modern loading cannot be expressed as a given equivalent in the Cooper system, otherwise an error of 20 to 37% will be introduced. As a measuring or rating standard for present-day traffic, the Cooper system yields results that are radically inconsistent.

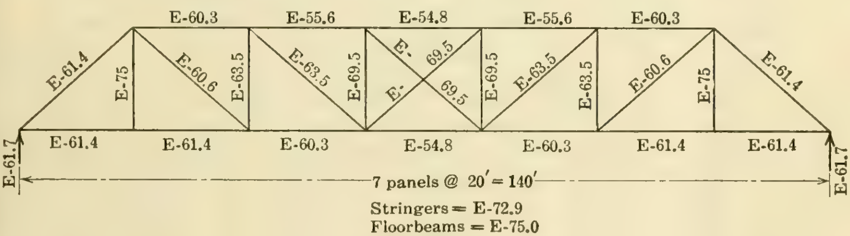


FIG. 1.

This disproportion between the Cooper system and actual modern loadings has made it almost prohibitively difficult for the railroads to "Cooperize" their bridges. The engineer of structures of one of the prominent lines recently told the writer that it had been given up as a hopeless task. When an attempt was made to fix the Cooper rating of a bridge designed for the road's actual equipment, one Cooper rating would be obtained for the stringers, another for the floor-beams, still another for the chord members, and a different rating again for the web members.

A simple illustration of this incommensurability of the Cooper system with modern loadings is given in Fig. 1, representing the Cooper rating dia-

gram of a 140-ft. span designed for the Pennsylvania Railroad N1S engines. The ratings shown are taken directly from Plate XV.

If the bridge is intended for the modern engine, but is designed according to Cooper's loading specification, there will be a relative overstressing or waste of metal in some of the parts, amounting to 37 per cent. Such variation or discrepancy appears to the writer to be a sufficient indictment against the Cooper system as a present-day specification.

The next step was to construct a graphic chart for rating the Composite Standard Loading (M-60) in terms of the Cooper system. This chart, presented on Plate XVI, was obtained by plotting the maximum E-ratings taken from the tabulation on Plate XV.

The kinks in this chart are not due to any irregularities in the Composite Standard; they represent the peculiarities of the Cooper loading diagram. The same irregularities are found in any chart or diagram relating to the Cooper loading, whereas a chart constructed for the Composite Standard (such as Plate XIII) is comparatively smooth and free from disturbing irregularities.

This chart (Plate XVI) can be used as a rating chart for comparing or converting the stresses from the Cooper loading and the stresses from the Composite Loading (M-60) proposed herein as a standard. Thus, at the middle of a 40-ft. span ($l_1 = 20$, $l_2 = 20$), the proposed loading is equivalent to Cooper's E-75. At the quarter-points of a 400-ft. span ($l_1 = 100$, $l_2 = 300$), the proposed loading is equivalent to Cooper's E-63.4.

Table 2 shows the Cooper ratings of the proposed loading (M-60), for various spans, obtained from Plate XVI and the corresponding table (Plate XV).

TABLE 2.—EQUIVALENT COOPER RATINGS OF THE PROPOSED COMPOSITE LOADING (M-60).

Spans.	E-rating for center moments.	E-rating for end shears.
10	E-72	E-72
20	E-73	E-74
30	E-74	E-73
40	E-75	E-72
50	E-73	E-70
60	E-72	E-71
70	E-72	E-71
80	E-73	E-71
90	E-73	E-70
100	E-73	E-69
120	E-71	E-68
140	E-69	E-67
160	E-68	E-67
180	E-67	E-66
200	E-66	E-66
250	E-65	E-65
300	E-63	E-65
400	E-62	E-64
500	E-61	E-63
600	E-61	E-63
700	E-61	E-62
800	E-61	E-62
900	E-60	E-62
1 000	E-60	E-62

TABLE OF EQUIVALENT COOPER RATINGS FOR HEAVIEST LOCOMOTIVE LOADINGS

	0	10	20	30	40	50	60	70	80	90	100	120	140	160	180	200	220	240	260	280	300	400	500	600	700	800	900	1000
1000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
900	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
800	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
700	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
600	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				
500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					
400	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]						
300	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]							
280	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								
260	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]									
240	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]										
220	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]											
200	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]												
180	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]													
160	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]														
140	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]															
120	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																
100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																	
90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																		
80	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																			
70	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																				
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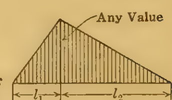

Any Triangular Influence Line

l_1 = Shorter segment of Influence Triangle
l_2 = Longer segment of Influence Triangle
q = Equivalent Uniform Load, taken from Table for the values of l_1 and l_2

This table can be used for finding maximum bending moments, shears, chord stresses, web stresses, counter stresses, end reactions, etc.

For Maximum Bending Moment at any section of any span
$$M = \tfrac{1}{2} \cdot q \cdot l_1 \cdot l_2$$

AXLE—LOAD DIAGRAMS (FOR 1 TRACK)

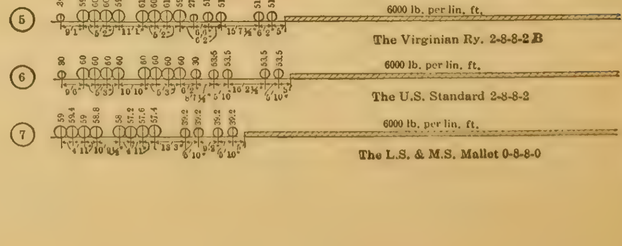

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PLATE XVI.
PAPERS, AM. SOC. C. E.
MAY, 1922.
STEINMAN ON
LOCOMOTIVE LOADINGS
FOR RAILWAY BRIDGES.

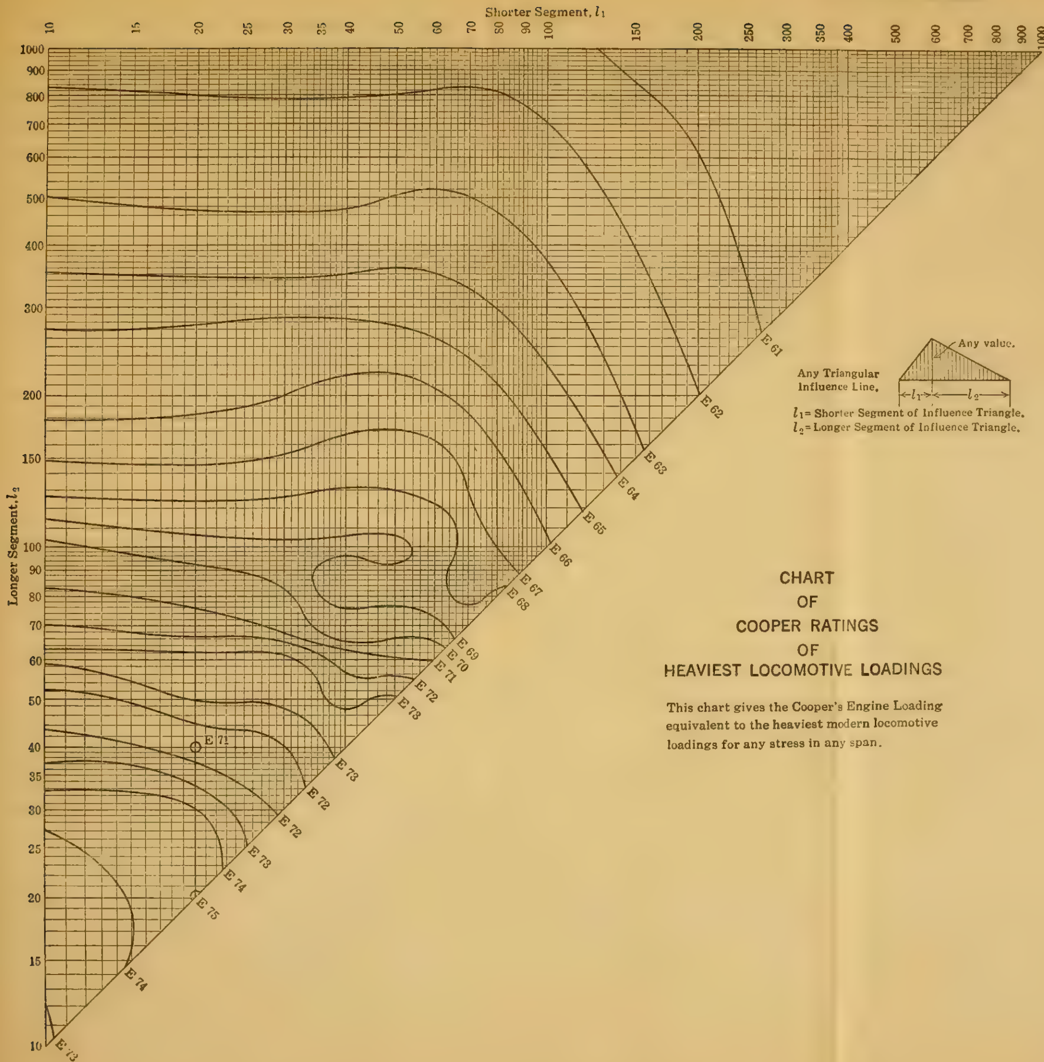


CHART OF COOPER RATINGS OF HEAVIEST LOCOMOTIVE LOADINGS

This chart gives the Cooper's Engine Loading equivalent to the heaviest modern locomotive loadings for any stress in any span.

Table 2 shows that the proposed Composite Loading (M-60) is equivalent to about Cooper's E-75 at short spans and to Cooper's E-60 at long spans. In other words, the Cooper rating of the proposed loading (M-60) gradually diminishes from E-75 to E-60 as the length of span is increased.

This variation shows that bridges of different span length in the same line will not be of uniform strength under modern loading, if they are designed for a uniform class of the Cooper loading. If designed for E-60, the shorter spans will be overstressed 25%; if designed for E-75, the longer spans will have a 25% waste of metal. Under these conditions, a single loading that will result in bridges of uniform strength for all spans and for all members in any span, should be preferred to the Cooper system. If designed for the proposed M-60 loading, all members of all spans will be of uniform strength under modern loading conditions, and any member of any span will be strong enough, without waste, to carry the heaviest existing locomotive loads.

Having constructed, as a substitute for the Cooper system, a composite of the heaviest existing locomotives in the form of a table (Plate XII) and a chart (Plate XIII) of maximum equivalent uniform loads, the problem of devising a more condensed and more tangible form of representing this new loading system will be discussed. In the following pages, the writer presents three alternative solutions of this problem:

1.—A proposed engine diagram, consisting of a simple conventional system of axle concentrations, followed by a uniform train load.

2.—A simplified loading diagram, consisting of a uniform load with a floating group of three excess concentrations.

3.—A loading formula, giving directly the equivalent uniform load for maximum stress at any section of any span.

These three alternative methods of specifying the proposed loading system will be presented and discussed in turn.

Proposed Engine Loading

The engine loading diagram devised to represent the composite of the heaviest existing locomotives is shown on Figs. 2, 3, 4, 5, 6, and 7, and Plate XVII.

Of necessity, a locomotive of the Mallet type was adopted. (Five of the seven heaviest locomotives, as shown on Plate XII, are of the Mallet type.)

Five axles to each group of drivers were found to be necessary. (Three of the four heaviest locomotives have Decapod grouping.)

This makes a total of ten driving axles, the same as in the heaviest locomotive loadings Nos. 2, 3, and 4. (In Nos. 5, 6, and 7, there are only eight driving axles. In No. 1, there are twelve driving axles).

In order to obtain the same stresses for small spans as are produced by the heavy group of driver concentrations of Locomotive No. 3 (Pennsylvania Railroad N1S), it was found necessary to make one group of axle loads in the proposed engine diagram, 75 000 lb. each. The axle loads in the other group were made 60 000 lb. each, in order to keep down the stresses for longer spans to the values produced by Locomotives Nos. 1 and 2.

The spacing of the 60 000-lb. axles was made 5 ft., as this is the closest spacing of such axles in any existing loading. The spacing of the 75 000-lb. axles was made 5½ ft., for the same reason. (In Locomotives Nos. 2, 5, 6, and 7, the 60 000-lb. axles are spaced approximately 5 ft. apart; and in Locomotives Nos. 1, 3, and 4, the heavier axles are spaced 5½ ft. apart.) The heavier group of axles was placed in the rear, following the precedent of Locomotive No. 1.

A pair of pilot wheels was added, as required by the stresses, in accordance with the precedent fixed by the six heaviest locomotives. The trailing wheels and tender, however, are considered as being absorbed in the uniform train load which follows the locomotive. As modern cars have concentrated loads exceeding those of the trailing wheels and tender, it is inconsistent refinement to represent the one by concentrations and the other by a uniform load.

The proposed engine diagram is thus reduced to a conventional 2-10-10 grouping of wheels, followed by a uniform train load of 6 000 lb. per lin. ft.

Although the engine diagram is really determined by the conditions previously set forth, the writer arrived at the same diagram by a synthetic method which closely fixed each axle load and each wheel spacing.

In constructing a chart of equivalent uniform loads, one begins with a wheel diagram and proceeds to find the corresponding equivalent uniform loads. In the present case, the problem is reversed: The equivalent uniform loads are listed for all sections of all spans in the table (Plate XII) and the chart (Plate XIII); it is required to construct a wheel diagram to fit these equivalent uniform loads throughout the entire range of spans and sections.

This problem is solved by starting with very short spans, and determining the necessary maximum concentration. Then, by successively lengthening the span considered, successive additional axle loads are determined in magnitude and relative position, until a point is reached where the further annexing of concentrations can be dispensed with and a uniform load substituted. This, in brief, is the method that was followed by the writer, except that minor modifications of the loads and spacings were introduced in order to secure greater uniformity and simplicity.

After the engine diagram was thus determined, it was found to give results very close to those obtained with the composite of the heaviest locomotives, except for slight variations due to the rounding off of the figures adopted.

In order to facilitate the use of the proposed engine diagram and at the same time to test its conformity with the Composite Standard, the equivalent uniform loads have been computed and are presented in tabular form in Fig. 2.

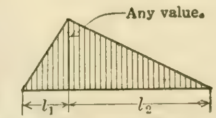
This table (Fig. 2) gives the equivalent uniform loads of the proposed engine loading (M-60) for all sections of all spans. It is found to check closely the maximum values in the similar table (Plate XII), constructed for the heaviest existing locomotive loadings.

Simple methods of using this table for calculating maximum bending moments, shears, and reactions are indicated. More complete instructions for calculating maximum stresses of all kinds from equivalent uniform loads will be found on Plate XI.

Shorter Segment l_1

Longer Segment l_2

	0	10	20	30	40	50	60	70	80	90	100	120	140	160	180	200	220	240	260	280	300	400	500	600	700	800	900	1000
1000	6589	6520	6500	6475	6450	6420	6400	6380	6360	6340	6310	6263	6220	6191	6167	6148	6132	6118	6108	6099	6091	6063	6047	6037	6030	6025	6021	6018
900	6652	6585	6560	6530	6500	6460	6445	6425	6400	6380	6350	6289	6243	6208	6182	6161	6144	6130	6117	6107	6098	6068	6051	6039	6032	6026	6022	
800	6731	6650	6620	6590	6560	6520	6490	6470	6440	6420	6390	6321	6269	6230	6201	6177	6158	6142	6129	6117	6107	6076	6054	6042	6034	6028		
700	6830	6740	6710	6670	6625	6590	6560	6540	6500	6470	6440	6360	6301	6257	6224	6197	6175	6157	6148	6129	6118	6080	6059	6045	6036			
600	6962	6855	6820	6770	6720	6670	6640	6610	6570	6540	6500	6410	6342	6291	6252	6221	6196	6176	6158	6144	6131	6089	6064	6049				
500	7143	7010	6960	6900	6840	6780	6750	6690	6670	6630	6580	6475	6395	6335	6289	6253	6223	6199	6179	6162	6148	6098	6071					
400	7406	7240	7160	7100	7025	6950	6920	6860	6810	6760	6700	6567	6469	6395	6339	6295	6260	6231	6206	6186	6169	6111						
300	7826	7600	7530	7410	7300	7170	7160	7100	7020	6940	6830	6704	6575	6481	6410	6354	6318	6274	6243	6218	6197							
280	7943	7675	7590	7490	7380	7270	7220	7140	7080	7000	6880	6738	6602	6503	6428	6369	6322	6284	6258	6226								
260	8072	7790	7700	7570	7450	7350	7300	7220	7150	7060	6950	6777	6632	6526	6447	6385	6335	6295	6262									
240	8222	7930	7800	7680	7550	7440	7380	7310	7220	7120	7020	6820	6665	6554	6468	6403	6350	6307										
220	8395	8080	7930	7790	7660	7540	7460	7400	7300	7200	7090	6868	6703	6583	6492	6421	6365											
200	8594	8250	8075	7920	7780	7650	7580	7500	7390	7280	7160	6923	6744	6615	6517	6143												
180	8825	8430	8230	8080	7910	7780	7710	7610	7500	7370	7240	6983	6790	6650	6547													
160	9110	8630	8430	8270	8080	7940	7860	7750	7620	7480	7340	7053	6844	6692														
140	9440	8930	8660	8470	8260	8120	8040	7900	7750	7600	7450	7132	6903															
120	9840	9250	8940	8680	8480	8340	8250	8100	7900	7760	7580	7230																
100	10 320	9610	9250	9000	8730	8600	8500	8390	8140	7940	7730																	
90	10 580	9810	9420	9150	8850	8750	8660	8480	8260	8050																		
80	11 180	10 000	9590	9300	9050	8940	8820	8640	8390																			
70	11 840	10 170	9730	9450	9250	9150	9020	8820																				
60	12 380	10 470	9860	9600	9500	9400	9230																					
50	12 840	11 100	10 250	9780	9700	9660																						
40	13 825	11 900	10 900	10 160	9930																							
30	15 820	12 920	11 650	10 550																								
20	17 630	13 990	12 685																									
10	21 750	14 250																										



Any Triangular Influence Line.

l_1 = Shorter Segment of Influence Triangle.
l_2 = Longer Segment of Influence Triangle.
q = Equivalent Uniform Load taken from Chart for the values of l_1 and l_2. Values given in pounds per linear foot per track.

This table can be used for figuring the maximum stress in any member or section of any span. It gives stresses approximately equal to the maximum stresses producible by the heaviest existing locomotive loadings.

For Maximum Bending Moment at any section of any span. l_1 and l_2 = the two segments of the span.

$$M = \tfrac{1}{2} \cdot q \cdot l_1 \cdot l_2$$

For Maximum End Reaction or End Shear, $l_1 = 0$ and l_2 = the span.

$$V = \tfrac{1}{2} \cdot q \cdot l_2$$

For Maximum Shear at any section of a span, $l_1 = 0$, l_2 = the longer segment of the span and l = the span.

$$V = \tfrac{1}{2} \cdot q \cdot l_2 \cdot \frac{l_2}{l}$$

For Maximum Floorbeam Reaction or stress in Hanger, l_1 and l_2 = the adjoining panel lengths

$$R = \tfrac{1}{2} \cdot q \cdot (l_1 + l_2)$$

TABLE OF EQUIVALENT UNIFORM LOADS (PER TRACK) FOR DESIGNING RAILWAY BRIDGES

Based on Proposed Engine Loading M-60

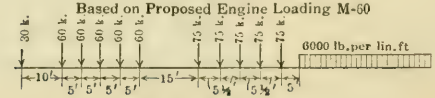


FIG. 2.

Fig. 3 is a conventional tabulation of load positions giving maximum stress under the proposed engine loading. It gives the wheel to be placed at the section for any combination of values of l_1 and l_2. The equivalent uniform loads tabulated in Fig. 2 correspond to the load positions given in this table (Fig. 3).

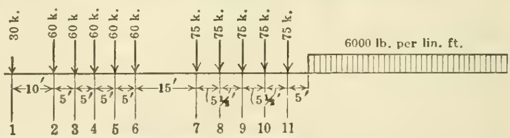
The table (Fig. 3) shows greater regularity than the corresponding table for the Cooper loading (Plate XI). For the proposed engine loading, this table (Fig 3) is hardly needed, as the wheel diagram is so simple and regular that load positions for maximum stress at any section can be decided by inspection. It is seldom necessary to try more than one load position for any maximum stress.

Shorter Segment l_1

Longer Segment l_2	0	10	20	30	40	50	60	70	80	90	100	120	140	160	180	200	220	240	260	280	300	400	500	600	700	800	900	1000
1000	2	3	3	4	5	6	7	8	9	9	10																	
900	2	3	3	4	5	6	7	8	9	9	10																	
800	2	3	3	4	5	6	7	8	9	9	10																	
700	2	3	3	4	5	6	7	8	9	9	10																	
600	2	3	3	4	5	6	7	8	9	9	10																	
500	2	3	3	4	5	6	7	8	9	9	10																	
400	2	3	3	4	5	6	7	8	9	9	10																	
300	2	3	3	4	5	6	7	8	9	10	10																	
280	2	3	3	4	5	6	7	8	9	10	10																	
260	2	3	3	4	5	7	7	8	9	10	10																	
240	2	3	3	4	5	7	7	8	9	10	10																	
220	2	3	3	4	5	7	7	8	9	10	10																	
200	2	3	3	4	6	7	7	8	9	10	10																	
180	2	3	3	5	6	7	8	8	9	10	10																	
160	2	3	3	5	6	7	8	8	9	10	10																	
140	2	3	4	5	6	7	8	8	9	10	10																	
120	2	3	4	5	6	7	8	8	9	10	10																	
100	2	3	4	5	6	8	8	9	9	10	10																	
90	2	3	4	5	6	8	8	9	9	10																		
80	$\overline{11}$	3	4	5	7	8	8	9	9																			
70	$\overline{11}$	3	5	5	7	8	8	9																				
60	$\overline{11}$	8	5	5	7	8	8																					
50	$\overline{11}$	8	9	8	7	8																						
40	$\overline{11}$	8	9	8	7																							
30	7	8	9	8																								
20	7	8	9																									
10	7	8																										

For $l_1 > 117\frac{1}{2}$ ft., place head of uniform train load at $117\frac{1}{2}$ ft. from head of span.

WHEEL DETERMINING MAXIMUM STRESS
PROPOSED ENGINE LOADING M-60



The shorter segment is ahead followed by the longer one, except wheel is overlined.

FIG. 3.

When l_1 increases beyond the value of 117.5 ft., the head of the uniform train load becomes fixed at that distance from the head of the span. Consequently, for all values of l_1 exceeding 117.5 ft., the equivalent uniform load, in kips per foot, is expressible by Equation (1):

$$q = 6 + \frac{35\,320}{l_1\,(l_1 + l_2)} \qquad (1)$$

For mid-span moments, $l_1 = l_2$, and Equation (1) reduces to:

$$q = 6 + \frac{17\,660}{l_2^{\,2}} \qquad (2)$$

Shorter Segment, l_1

Larger Segment, l_2	0	10	20	30	40	50	60	70	80	90	100	120	140	160	180	200	220	240	260	280	300	400	500	600	700	800	900	1000
1000	99.9	99.7	100.0	100.0	100.2	100.0	100.0	99.7	99.7	99.7	99.5	99.4	100.0	99.5	99.6	99.7	99.7	99.5	99.7	99.8	99.9	99.8	100.0	99.9	100.0	100.0	100.0	100.0
900	99.8	99.8	100.0	99.9	100.0	99.7	99.8	99.8	99.7	99.7	99.5	99.2	100.0	99.6	99.8	99.7	99.7	99.7	99.7	99.8	100.0	99.9	100.0	100.0	100.0	100.0	100.0	
800	99.8	99.5	99.7	99.5	100.0	99.7	99.5	99.5	99.4	99.7	99.9	99.4	99.5	99.5	99.6	99.5	99.7	99.8	99.7	99.7	99.0	99.9	99.9	99.9	100.0	100.0		
700	99.8	99.7	99.9	100.2	100.0	100.1	100.0	100.0	100.0	99.8	99.7	99.4	99.7	99.5	99.5	99.5	99.8	99.7	99.9	99.7	99.7	99.9	100.0	100.0	100.0			
600	99.8	100.0	99.7	99.6	99.5	99.5	99.4	99.5	99.6	99.7	100.0	99.5	99.4	99.5	99.5	99.5	99.5	99.7	99.7	99.8	99.8	99.9	99.9	100.0				
500	99.8	99.5	99.7	99.7	99.8	99.4	99.3	99.2	99.6	99.5	99.7	99.6	99.3	99.4	99.5	99.5	99.5	99.3	99.7	99.7	99.8	99.8	99.9					
400	99.8	100.0	99.5	99.7	99.5	99.6	99.7	99.1	99.9	99.4	99.1	99.2	99.5	99.2	99.4	99.5	99.5	99.5	99.5	99.6	99.7	99.8						
300	99.8	100.0	100.1	99.6	99.5	98.5	99.5	99.5	99.7	99.2	99.0	99.8	99.3	99.0	99.2	99.3	99.6	99.5	99.5	99.4	99.6							
280	99.8	99.2	99.4	99.6	99.8	99.0	99.4	99.5	99.7	99.5	98.8	98.5	99.0	99.1	99.2	99.4	99.4	99.5	99.6	99.5								
260	99.8	99.5	99.7	99.3	99.1	99.0	99.5	99.2	99.8	99.4	98.7	98.5	99.0	99.0	99.2	99.4	99.3	99.5	99.5									
240	99.9	99.9	99.8	99.8	99.4	99.2	99.2	99.6	99.7	99.2	99.2	98.8	99.0	99.0	99.2	99.2	99.4	99.5										
220	100.0	99.2	99.6	99.5	99.5	99.3	99.2	99.5	98.9	99.4	99.3	98.4	98.6	99.0	99.1	99.2	99.0											
200	100.0	100.2	99.7	99.5	99.7	99.1	99.2	99.5	99.3	99.2	99.1	98.4	98.6	98.0	99.0	99.3												
180	100.1	100.3	99.9	99.8	99.9	98.7	99.9	99.4	99.5	99.0	99.2	98.0	98.7	98.7	99.0													
160	100.2	99.9	99.9	100.1	99.8	99.2	99.5	99.9	99.5	99.2	99.3	98.2	98.4	99.3														
140	100.0	100.1	99.5	99.9	100.0	99.5	99.9	100.0	99.4	99.5	99.0	98.2	98.1															
120	99.8	100.1	99.5	99.5	99.7	99.5	100.3	100.6	99.3	99.3	98.7	98.2																
100	99.5	99.5	99.3	99.5	99.5	99.8	100.5	101.5	100.0	99.3	98.6																	
90	99.8	99.3	99.1	99.5	99.4	99.5	101.2	101.2	99.7	99.2																		
80	102.1	99.0	98.9	99.1	100.1	100.5	101.4	101.6	99.[illegible]																			
70	105.2	98.2	99.1	98.7	100.6	101.0	102.0	102.1																				
60	106.7	99.4	97.6	98.5	101.0	101.6	102.1																					
50	105.0	103.5	100.1	99.3	102.0	101.8																						
40	102.4	103.3	104.8	99.6	100.4																							
30	106.2	101.7	102.3	102.3																								
20	95.8	102.2	102.9																									
10	96.3	97.7																										

PERCENTAGE RATINGS

OF

PROPOSED ENGINE LOADING—M-60

IN TERMS OF

HEAVIEST LOCOMOTIVE LOADINGS

FIG. 4.

For end shears in spans of 90 ft. or more, the proposed engine loading yields an equivalent uniform load expressible by Equation (3):

$$q = 6 + \frac{606}{l_2} - \frac{17\,440}{l_2^{\,2}} \quad \text{..........} (3)$$

The use of Equations (1), (2), and (3), and other similar formulas, greatly simplified the computation of the equivalent uniform loads for the table on Fig 2. Moreover, these formulas represent continuous functions of l_1 and l_2 over wide areas, and, therefore, contribute to smoothness and regularity in charts or diagrams of equivalent uniform loads constructed for the proposed engine loading (Plate XVII and Figs. 5 and 6).

The remarkably close correspondence between the proposed engine loading (M-60) and the composite of the heaviest existing locomotives is shown in the comparative rating table, Fig. 4. This table gives, for each point, the percentage ratio of the equivalent uniform load for the proposed engine loading to the corresponding equivalent uniform load of the Composite Standard. The percentages tabulated are simply the ratios of the values in Fig. 2 to the corresponding maximum values in Plate XII.

The tabulated ratios are all close to 100%; with few exceptions the variation is less than 1 per cent. At a few points, confined to very short spans, some larger variations are found, with extreme values of — 4 and + 6 per cent. These variations could have been eliminated by making one or two of the heavy axle loads in the proposed engine loading slightly more than 75 000 lb. and the adjacent axle loads correspondingly less; but the writer considered it wiser to sacrifice such hair-splitting refinement for the sake of the greater simplicity and convenience resulting from the use of five equal axle loads of 75 000 lb. The writer doubts whether any closer agreement with the Composite Standard could be obtained by the use of any other engine diagram of equal simplicity.

Having computed the equivalent uniform loads for the proposed engine loading (Fig. 2), and having verified (Fig. 4) their close agreement with the Composite Standard previously established (Plate XII), the next step was to present the values in graphic form for easier application. This is done in Plate XVII which is a chart of equivalent uniform loads for the proposed engine loading and on which are notes that explain its use.

This chart (Plate XVII) agrees closely with the corresponding chart for the Composite Standard (Plate XIII). The maximum variation between corresponding curves on the two charts is, except for a few unimportant points, only 1 or 2 per cent.

The curves on the chart (Plate XVII) are remarkably smooth and regular for curves derived from a loading diagram with wheel concentrations. They are free from the kinks and irregularities found in charts based on the Cooper engine diagram, which are attributable to certain minor anomalies inherent in the Cooper loading.

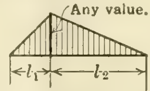
If the proposed engine loading (M-60) is adopted, this chart (Plate XVII) can be incorporated in any set of printed specifications as a time saver in calculating live load stresses. It gives the maximum stresses produced by

Equivalent Uniform Loads for Shears and Reactions
($l_1 = 0$)

l_2	1000	900	800	700	600	500	400	300	280	260	240	220	200	180	160	140	120	100	90	80	70	60	50	40	30	20	10
q	6589	6652	6731	6830	6962	7143	7406	7826	7943	8072	8222	8395	8594	8825	9110	9440	9840	10 320	10 580	11 180	11 840	12 380	12 840	13 825	16 430	17 630	21 750

This Chart can be used for figuring the maximum stress in any member or section of any span. It gives stresses approximately equal to the maximum stresses producible by the heaviest existing locomotive loadings.

Any Triangular Influence Line.



l_1 = Shorter Segment of Influence Triangle.
l_2 = Longer Segment of Influence Triangle.
q = Equivalent Uniform Load taken from Chart for the values of l_1 and l_2
Values given in pounds per foot per track.

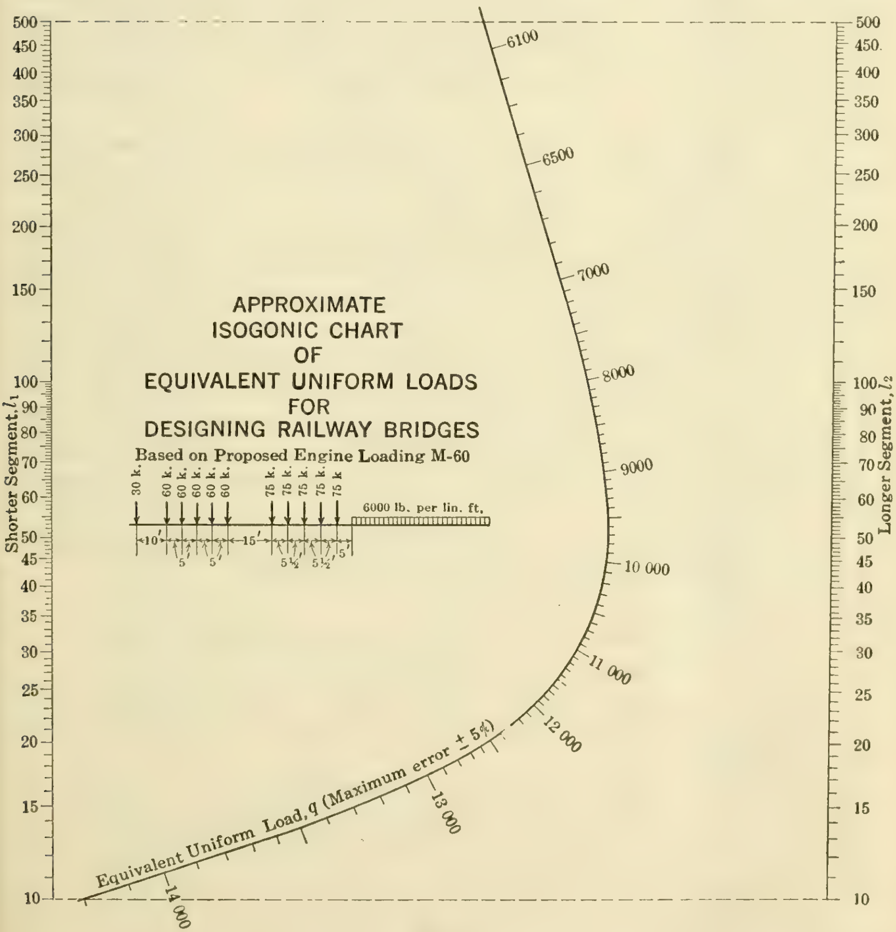


FIG. 5.

M-60, which are nearly equal to the maximum stresses producible by the heaviest existing locomotive loadings.

In Fig. 5, there is presented a greatly simplified form of chart of equivalent uniform loads devised by the writer. It is in the form of an isogonic or straight-line diagram constructed by a new empirical method.

Since the relation for a given engine diagram between the equivalent uniform loads (q) and the span segments (l_1 and l_2) is not expressible as a continuous function, either logarithmic or otherwise, an ordinary nomographic diagram with straight axes cannot be applied. As an alternative, the writer decided to plot the values of q in a logarithmic field, and to use the mean curve thus obtained as the q-axis. The result is shown in Fig. 5. This simple isogonic chart gives the equivalent uniform loads for the proposed engine loading (M-60). It is, of necessity, slightly approximate; but the largest error resulting from its use is only ± 4.2 per cent. This diagram possesses advantages of simplicity and ease of reproduction, which counterbalance the advantage of greater precision of the preceding chart (Plate XVII).

An attempt to construct a similar nomographic diagram for the Cooper loading was abandoned, as the inherent peculiarities of that loading made it impossible to obtain an acceptable result.

The small error of $\pm$ 4.2% in the isogonic chart (Fig. 5) could be still further reduced by substituting curved axes for l_1 and l_2. It requires merely a repetition of the operation by which the curved axis for q was obtained. By successive repetition of this procedure, a final isogonic chart may be obtained to give results with almost any desired degree of accuracy. The writer submits this as a suggested method for constructing an isogonic chart for any three variables between which there is a relation that is more or less regular, but which is not expressible by any continuous formula. This isogonic chart (Fig. 5) may be incorporated in specifications based on the proposed engine loading (M-60).

In Fig. 6 there is presented, in more familiar form, a graphic comparison between the different loadings under consideration, namely:

(1) Cooper's E-60 loading;

(2) The composite of the heaviest existing locomotives; and

(3) The proposed engine loading (M-60).

The stress-producing effects of these loadings are represented by graphs of equivalent uniform loads for end shears and center moments for spans of varying length.

For both shears and moments, the Composite Standard is about 25% heavier than Cooper's E-60 at short spans and gradually approaches coincidence with the latter at very long spans. If Cooper's E-75 is substituted, it will cause an excess of 25% at long spans.

For end shears, there is the slight discrepancy of a few per cent., previously mentioned, between the Composite Standard and the proposed engine loading (M-60) at short spans. Except for spans of less than 24 ft., the variation is on the side of safety. For spans of more than 90 ft., the two

PLATE XVII.
PAPERS, AM. SOC. C. E.
MAY, 1922.
STEINMAN ON
LOCOMOTIVE LOADINGS
FOR RAILWAY BRIDGES.

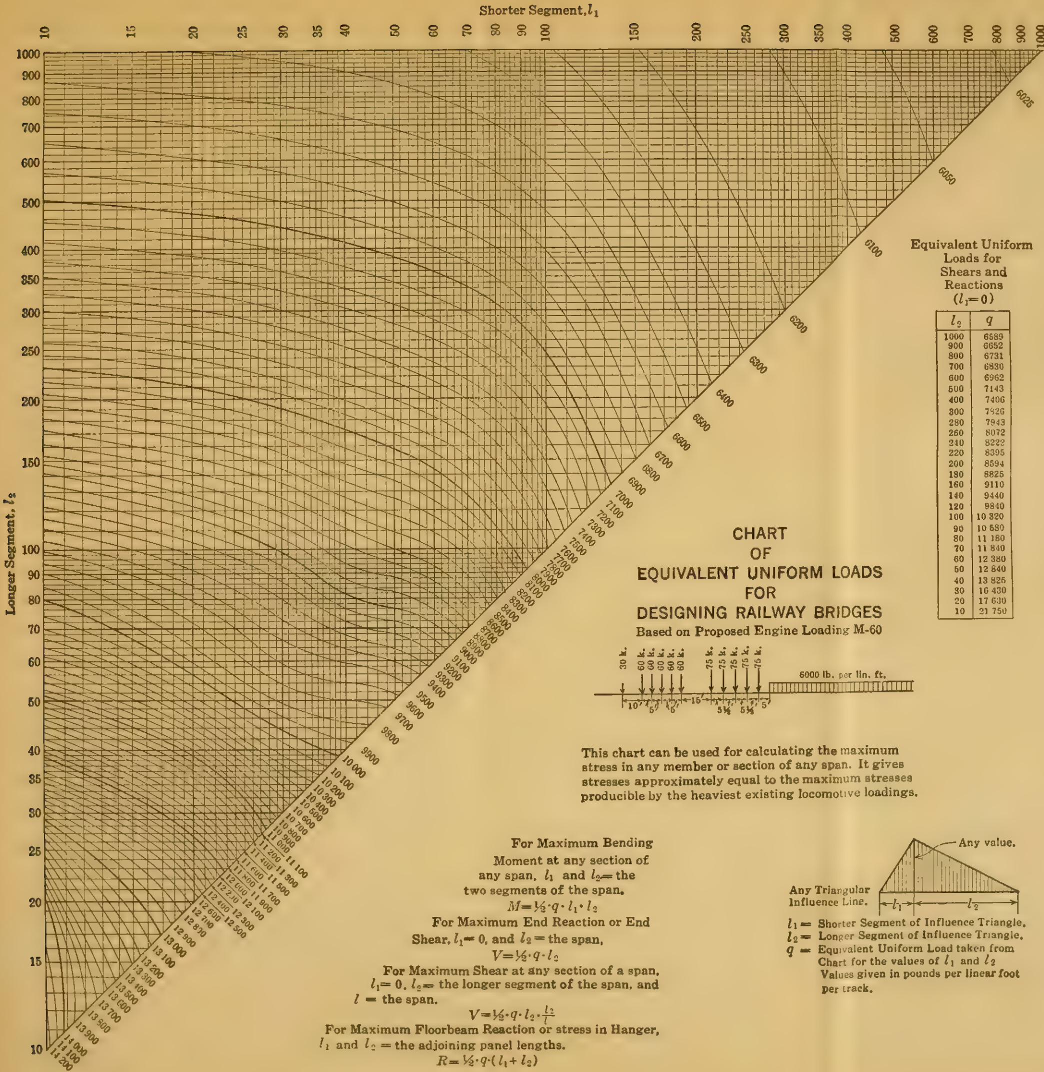


CHART OF EQUIVALENT UNIFORM LOADS FOR DESIGNING RAILWAY BRIDGES

Based on Proposed Engine Loading M-60

This chart can be used for calculating the maximum stress in any member or section of any span. It gives stresses approximately equal to the maximum stresses producible by the heaviest existing locomotive loadings.

Equivalent Uniform Loads for Shears and Reactions ($l_1 = 0$)

l_2	q
1000	6589
900	6652
800	6731
700	6830
600	6962
500	7143
400	7406
300	7926
280	7943
260	8072
240	8222
220	8395
200	8594
180	8825
160	9110
140	9440
120	9840
100	10 320
90	10 580
80	11 180
70	11 840
60	12 380
50	12 840
40	13 825
30	16 430
20	17 630
10	21 750

For Maximum Bending Moment at any section of any span, l_1 and l_2 = the two segments of the span.

$$M = \tfrac{1}{2} \cdot q \cdot l_1 \cdot l_2$$

For Maximum End Reaction or End Shear, $l_1 = 0$, and l_2 = the span,

$$V = \tfrac{1}{2} \cdot q \cdot l_2$$

For Maximum Shear at any section of a span, $l_1 = 0$, l_2 = the longer segment of the span, and l = the span.

$$V = \tfrac{1}{2} \cdot q \cdot l_2 \cdot \frac{l_2}{l}$$

For Maximum Floorbeam Reaction or stress in Hanger, l_1 and l_2 = the adjoining panel lengths.

$$R = \tfrac{1}{2} \cdot q \cdot (l_1 + l_2)$$

l_1 = Shorter Segment of Influence Triangle.
l_2 = Longer Segment of Influence Triangle.
q = Equivalent Uniform Load taken from Chart for the values of l_1 and l_2.
Values given in pounds per linear foot per track.

curves coincide, indicating that the proposed engine loading is the exact equivalent of the Composite Standard in this range.

In the graphs for center moments, there is a remarkable agreement between the proposed engine loading (M-60) and the Composite Standard. The two curves follow each other throughout, with maximum variations of only 1 or 2%, except for one point having a difference of 2.9 per cent.

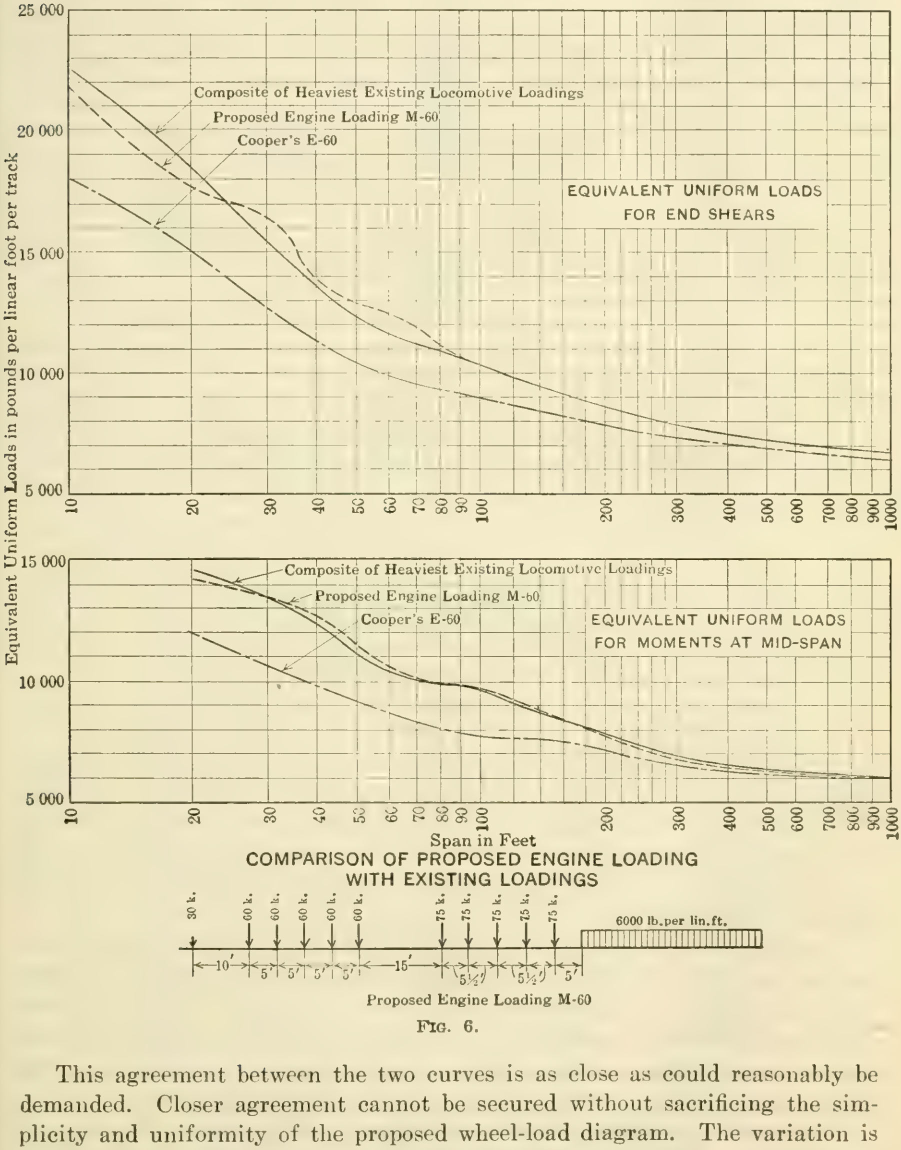


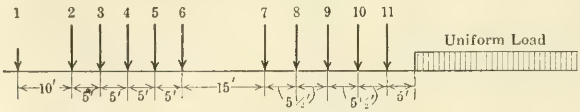
Fig. 6.

This agreement between the two curves is as close as could reasonably be demanded. Closer agreement cannot be secured without sacrificing the simplicity and uniformity of the proposed wheel-load diagram. The variation is so small that the proposed engine loading (M-60) may safely be accepted as a close equivalent of the composite of the heaviest existing locomotives.

The tabulation in Fig. 7 shows how the proposed engine loading can be diminished or augmented in fixed ratios to form different classes, in the same manner as the Cooper system of engines.

After conference with other engineers, the writer has decided to designate the proposed engine loading, previously derived, as equivalent to the heaviest modern locomotives, by the class symbol, M-60. The letter, M, stands for "Modern", "Motive Power", or "Mallet". The class number is made 60 to symbolize, in the conventional manner, the weights of the first group of driver axles and the weight of the uniform train load. An additional reason for the designation, 60, was to simplify the conversion to different classes.

PROPOSED ENGINE LOADING SYSTEM
FOR DESIGN OF RAILWAY BRIDGES



Loads per Track

M-10 = 5	10	10	10	10	10	12.5	12.5	12.5	12.5	12.5	1000 lb. per lin. ft.
M-40 = 20	40	40	40	40	40	50	50	50	50	50	4000
M-50 = 25	50	50	50	50	50	62.5	62.5	62.5	62.5	62.5	5000
M-60 = 30	**60**	**60**	**60**	**60**	**60**	**75**	**75**	**75**	**75**	**75**	**6000**
M-70 = 35	70	70	70	70	70	87.5	87.5	87.5	87.5	87.5	7000
M-80 = 40	80	80	80	80	80	100	100	100	100	100	8000
M-90 = 45	90	90	90	90	90	112.5	112.5	112.5	112.5	112.5	9000

Loading M-60 will give stresses for all spans very close to the maximum stresses producible by the heaviest existing locomotive loadings. It is approximately equivalent to Cooper's E-75 for short spans and to Cooper's E-60 for long spans

Fig. 7.

Reducing the proposed engine loading to Class M-10, as a basic unit, there is a pilot axle of 5 k., five driver axles of 10 k., and five driver axles of 12.5 k., followed by a uniform load of 1 000 lb. per lin. ft. This simple loading is all that need be given in a specification. By multiplying this unit loading, M-10, by 4, 5, 6, 7, 8, or 9, the loadings, M-40, M-50, M-60, M-70, M-80, and M-90 are obtained.

Loading M-60 will give stresses for all spans very close to the maximum stresses producible by the heaviest existing locomotive loadings. To allow for probable future increase in weight of traffic, the writer would recommend that Loading M-50 be specified in present-day specifications with a provision for an excess loading of 50%; or, what amounts to the same thing, Loading M-60 may be specified with a provision for an excess loading of 25 per cent.

For spans up to 100 ft. the proposed Loading M-50 is about equivalent to Cooper's E-60. This is shown by Table 3 which gives the equivalent Cooper ratings of the proposed Loading M-50 for spans from 10 to 1 000 ft

TABLE 3.—EQUIVALENT COOPER RATINGS OF THE PROPOSED ENGINE LOADING (M-50).

Spans.	E-rating for center moments.	E-rating for end shears.
10	E-60	E-60
20	E-59	E-59
30	E-62	E-62
40	E-64	E-61
50	E-63	E-62
60	E-61	E-63
70	E-61	E-62
80	E-61	E-60
90	E-62	E-58
100	E-62	E-57
120	E-60	E-57
140	E-58	E-56
160	E-56	E-56
180	E-55	E-55
200	E-54	E-55
250	E-53	E-54
300	E-52	E-54
400	E-51	E-53
500	E-51	E-52
600	E-50	E-52
700	E-50	E-52
800	E-50	E-52
900	E-50	E-52
1 000	E-50	E-51

It will be observed, from Table 3, that the Cooper equivalent of M-50 diminishes from E-64 at short spans to E-50 at very long spans.

A reverse rating or conversion table is presented in Table 4 which gives the M-ratings of Cooper's E-60 loading for various spans.

TABLE 4.—EQUIVALENT M-RATINGS OF COOPER'S E-60 LOADING.

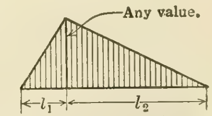
Spans.	M-rating for center moments.	M-rating for end shears.
10	M-50	M-50
20	M-51	M-51
30	M-49	M-48
40	M-47	M-49
50	M-48	M-49
60	M-49	M-48
70	M-49	M-48
80	M-49	M-50
90	M 48	M-52
100	M-48	M-52
120	M-50	M-53
140	M-52	M-54
160	M-53	M-54
180	M-54	M-54
200	M-55	M-55
250	M-57	M-56
300	M-58	M-56
400	M-59	M-57
500	M-59	M-57
600	M-60	M-57
700	M-60	M-58
800	M-60	M-58
900	M-60	M-58
1 000	M-60	M-59

According to Table 4, the M equivalent of Cooper's E-60 ranges between M-47 at short spans and M-60 at long spans; but it is fairly well represented by M-50 for all spans below 100 ft.

Shorter Segment l_1

Longer Segment l_2	0	10	20	30	40	50	60	70	80	90	100	120	140	160	180	200	220	240	260	280	300	400	500	600	700	800	900	1000
1000	6527	6522	6517	6512	6507	6502	6497	6493	6488	6484	6480	6471	6462	6455	6447	6400	6432	6425	6418	6412	6405	6376	6351	6330	6310	6294	6279	6265
900	6585	6577	6570	6565	6560	6553	6547	6542	6536	6531	6526	6515	6505	6496	6487	6478	6469	6461	6453	6445	6438	6405	6376	6351	6330	6310	6294	
800	6655	6646	6638	6631	6625	6616	6609	6602	6596	6590	6582	6570	6558	6545	6535	6525	6515	6505	6495	6485	6476	6436	6404	6375	6352	6329		
700	6745	6735	6725	6715	6705	6695	6685	6675	6667	6660	6653	6635	6620	6605	6593	6580	6567	6550	6543	6532	6521	6475	6436	6403	6375			
600	6865	6850	6835	6825	6815	6800	6785	6775	6765	6750	6740	6720	6700	6680	6665	6650	6635	6620	6605	6590	6576	6520	6474	6435				
500	7030	7010	6990	6970	6950	6935	6920	6905	6890	6875	6860	6830	6805	6780	6755	6735	6715	6695	6676	6660	6643	6575	6520					
400	7270	7240	7210	7180	7155	7130	7105	7080	7055	7035	7015	6975	6940	6905	6875	6845	6820	6795	6772	6750	6730	6640						
300	7660	7600	7550	7505	7460	7420	7380	7345	7310	7275	7240	7185	7130	7080	7040	7000	6965	6930	6900	6870	6840							
280	7760	7700	7650	7590	7540	7490	7450	7410	7370	7335	7300	7235	7175	7130	7080	7040	7000	6960	6925	6895								
260	7890	7820	7750	7690	7630	7580	7530	7480	7440	7400	7360	7290	7230	7175	7125	7080	7035	6995	6960									
240	8020	7940	7870	7800	7740	7680	7620	7570	7520	7470	7430	7350	7290	7225	7170	7120	7075	7030										
220	8190	8090	8000	7920	7850	7780	7720	7660	7600	7550	7500	7420	7350	7280	7220	7165	7115											
200	8380	8260	8160	8070	7980	7900	7830	7760	7700	7640	7585	7500	7420	7345	7280	7215												
180	8600	8460	8340	8230	8120	8040	7950	7870	7800	7730	7680	7580	7490	7410	7330													
160	8870	8700	8550	8420	8280	8190	8090	8000	7910	7850	7790	7670	7570	7480														
140	9190	8980	8800	8630	8480	8360	8240	8140	8050	7970	7900	7770	7650															
120	9600	9320	9090	8880	8700	8540	8400	8300	8200	8110	8030	7870																
100	10 110	9740	9420	9160	8940	8740	8610	8490	8370	8260	8160																	
90	10 400	9960	9600	9300	9040	8860	8600	8580	8450	8340																		
80	10 730	10 260	9780	9440	9150	8990	8830	8680	8540																			
70	11 070	10 440	9940	9550	9300	9110	8930	8760																				
60	11 400	10 630	10 050	9600	9420	9210	9000																					
50	12 340	11 280	10 530	9690	9480	9240																						
40	13 650	12 120	11 100	10 370	9820																							
30	15 600	13 200	11 760	10 800																								
20	18 600	14 400	12 300																									
10	24 000	15 000																										

Any Triangular Influence Line.



l_1 = Shorter Segment of Influence Triangle.
l_2 = Longer Segment of Influence Triangle.
q = Equivalent Uniform Load taken from Chart for the values of l_1 and l_2. Values given in pounds per linear foot per track.

This table can be used for figuring the maximum stress in any member or section of any span. It gives stresses approximately equal to the maximum stresses producible by the heaviest existing locomotive loadings.

For Maximum Bending Moment at any section of any span. l_1 and l_2 = the two segments of the span.

$$M = \tfrac{1}{2} \cdot q \cdot l_1 \cdot l_2$$

For Maximum End Reaction or End Shear, $l_1 = 0$ and l_2 = the span.

$$V = \tfrac{1}{2} \cdot q \cdot l_2$$

For Maximum Shear at any section of a span, $l_1 = 0$, l_2 = the longer segment of the span and l = the span.

$$V = \tfrac{1}{2} \cdot q \cdot l_2 \cdot \frac{l_2}{l}$$

For Maximum Floorbeam Reaction or stress in Hanger, l_1 and l_2 = the adjoining panel lengths

$$R = \tfrac{1}{2} \cdot q \cdot (l_1 + l_2)$$

TABLE
OF
EQUIVALENT UNIFORM LOADS (PER TRACK)
FOR
DESIGNING RAILWAY BRIDGES

Based on Proposed Simplified Loading M-60

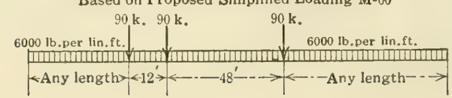
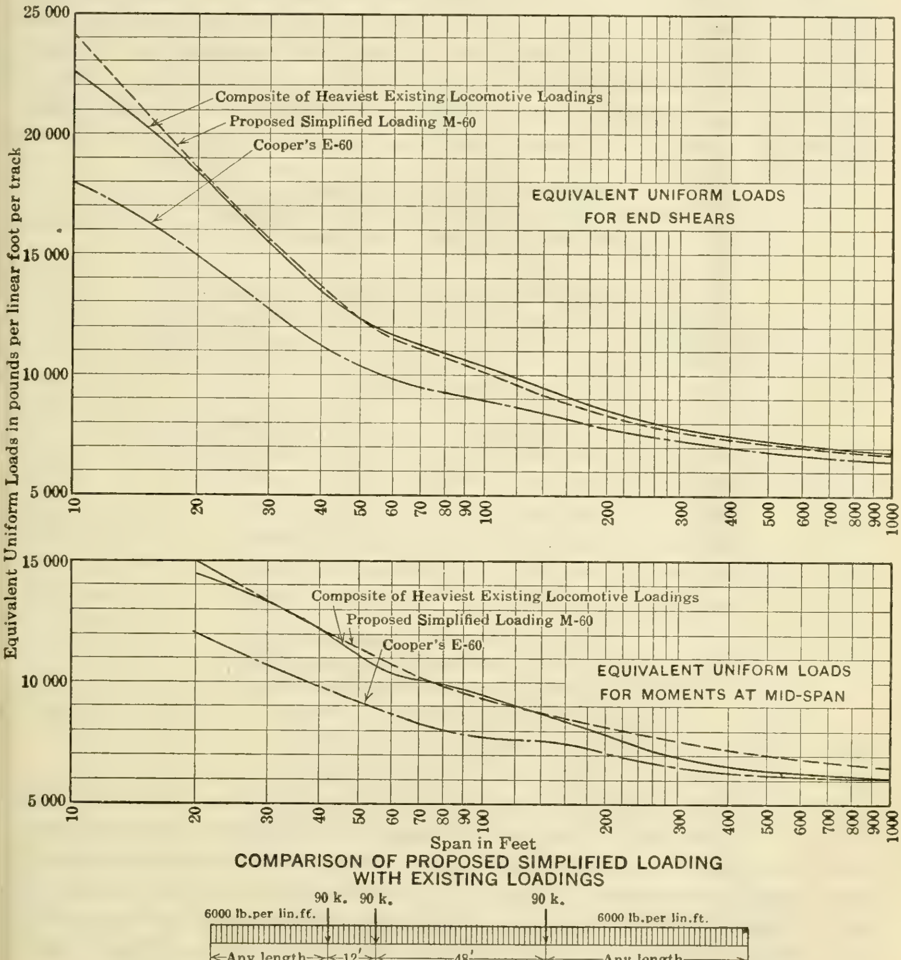


FIG. 8.

Proposed Simplified Loading

As an alternative for the proposed engine diagram to represent the composite of the heaviest existing locomotives, the writer has devised an equivalent simplified loading which has certain advantages and may be preferred by some engineers.



Proposed Simplified Loading M-60

Fig. 9.

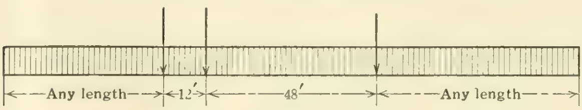
This proposed simplified loading (Figs. 8, 9, and 10) consists of a continuous uniform load of 6 000 lb. per lin. ft., on which is superimposed a floating group of excess concentrations. These concentrations, determined after a number of trials, consist of three 90 000-lb. loads spaced 12 ft. and 48 ft. apart, respectively.

The use of a simplified loading of this form greatly facilitates the computation of maximum stresses. Any stress is calculated by simply considering the

uniform load and then adding the independent contribution of the group of concentrations. The latter contribution is quickly found; there are only three concentrations and they are easily placed and easily calculated. For stringer and floor-beam spans, only the first two concentrations enter.

To expedite still further the calculation of maximum stresses for this proposed simplified loading, and to permit direct comparison with the composite of the heaviest existing locomotives, a table of equivalent uniform loads is presented in Fig. 8. The computation of this table consumed only a small fraction of the time required for the similar table of equivalent uniform loads (Fig. 2) for the proposed engine loading, indicating the greater convenience and despatch of stress computations with the simplified loading.

PROPOSED SIMPLIFIED LOADING
UNIFORM LOAD WITH EXCESS CONCENTRATIONS
FOR DESIGN OF RAILWAY BRIDGES



Loads per Track

M-10	15	15	15	1000 lb. per lin. ft.
M-40	60	60	60	4000
M-50	75	75	75	5000
M-60	**90**	**90**	**90**	**6000**
M-70	105	105	105	7000
M-80	120	120	120	8000
M-90	135	135	135	9000

Loading M-60 will give stresses for all spans very close to the maximum stresses producible by the heaviest existing locomotive loadings. It is approximately equivalent to Cooper's E-75 for short spans and to Cooper's E-60 for long spans

FIG. 10.

Comparison of the values in this table (Fig. 8) with the equivalent uniform loads for the composite of the heaviest locomotives (Plate XII) shows a sufficient agreement for all practical purposes. With the exception of some end shear values, where there is a maximum deficiency of 2.7%, the variations are on the side of safety. In other words, the proposed simplified loading will yield stresses equal to or somewhat greater than the heaviest existing locomotive loadings. Closer agreement could have been secured by varying the concentrated loads, but it was deemed preferable to keep the three concentrations equal for the sake of simplicity.

Moment and shear graphs comparing the simplified loading with existing loadings are presented in Fig. 9. The shear graph closely follows the curve for the Composite Standard, except for a variation of a few per cent. (on the safe side) at very short spans. The moment graph also follows the Composite Standard curve up to a span of about 200 ft., where it begins to deviate (on the safe side) with a maximum excess of about 10% at 500-ft. span.

It may be noted that the moment and shear graphs for the simplified loading are smoother than the corresponding curves for either the Composite Standard or the proposed engine loading.

To provide for different loading classes, similar to the different classes in the Cooper system, the proposed simplified loading can also be expressed in multiples of a smaller unit loading, as indicated in Fig. 10.

The simplified loading described, approximately equivalent to the heaviest modern locomotives, is called M-60. Accordingly, Loading M-10 consists of a uniform load of 1 000 lb. per lin. ft. with three excess concentrations of 15 k. each. Classes M-40, M-50, M-60, M-70, etc., are simply the corresponding multiples of Loading M-10.

For present-day specifications, as previously suggested, the writer would recommend Loading M-50 with provision for an increase of 50% or, what is equivalent, Loading M-60 with provision for an increase of 25 per cent.

Proposed Loading Formula

As a third alternative solution of the problem of representing the composite of the heaviest locomotives in more condensed form, the writer offers a loading formula which gives directly the equivalent uniform load at any section of any span.

In the opinion of other engineers besides the writer, this is an ideal solution of the problem, as a formula possesses many advantages over an engine diagram:

1.—It yields results of singular smoothness and regularity, unattainable with any diagram of wheel concentrations. The minor irregularities in stress variation due to unavoidable peculiarities in any concrete engine diagram are eliminated.

2.—It is a time saver, as it yields maximum stresses directly without the labor of shifting a wheel-load diagram and calculating the contributions of individual concentrations.

3.—It facilitates the construction of tables, stress diagrams, and charts, and yields diagrams of greater simplicity, smoothness, and accuracy.

4.—It is more easily remembered than a wheel-load diagram, and saves repeated reference to the specifications.

5.—It makes the designer independent of reference books, as the ordinary slide-rule takes the place of all tables, diagrams, and charts.

6.—It is more flexible than a wheel-load diagram, being more easily modified to adjust it to any desired change in variation of equivalent loads with length of span.

7.—It is more scientific than an arbitrary loading diagram.

The formula devised by the writer to represent the maximum equivalent uniform loads of the heaviest existing engines, as tabulated on Plate XII and plotted on Plate XIII, is presented in Figs. 11, 12, 13, and 14, and Plates XVIII and XIX, inclusive. It is as follows:

$$q = 5\,000 + 60\,000 \frac{\sqrt{l_2}}{l_1 + l_2} \qquad (4)$$

in which,

l_1 = the shorter segment of the influence triangle for any stress;
l_2 = the longer segment of the influence triangle; and
q = the corresponding equivalent uniform load for maximum stress.

To obtain Equation (4), the writer platted the composite values of q for varying spans on logarithmic cross-section paper. He soon found that the graphs representing q — 5 000 were closely approximated by straight lines having a slope corresponding to the convenient exponent, $\frac{1}{2}$. The graph for end shears yielded Equation (5), as follows:

$$q = 5\,000 + \frac{60\,000}{\sqrt{\text{span}}} \qquad (5)$$

and the graph for center moments yielded Equation (6):

$$q = 5\,000 + \frac{30\,000}{\sqrt{\frac{1}{2}\text{ span}}} \qquad (6)$$

The resemblance between Equations (5) and (6) at once suggested that they could be considered as two special cases of one general formula, namely,

$$q = 5\,000 + \frac{r \times 60\,000}{\sqrt{r \times \text{span}}} \qquad (7)$$

in which r = the position ratio in the span of the section considered. For end shears, the section is at the end of the span, consequently, $r = 1$, yielding Equation (5). For center moments, the section is at mid-span, consequently, $r = \frac{1}{2}$, yielding Equation (6). For maximum bending moment or chord stresses at the quarter-point of a span, $r = \frac{3}{4}$, and Equation (7) would yield:

$$q = 5\,000 + \frac{45\,000}{\sqrt{\frac{3}{4}\text{ span}}} \qquad (8)$$

For maximum shear at the quarter-points of a span, the equivalent uniform load is the same as for end shear in a span only three-quarters as long, consequently,

$$q = 5\,000 + \frac{60\,000}{\sqrt{\frac{3}{4}\text{ span}}} \qquad (9)$$

These examples show how simple the actual application of the formula becomes.

In order to facilitate the application of Equation (7) to finding maximum stresses of all kinds, it is expressed in more general form by introducing the symbols, l_1 and l_2, for the two segments of the loaded length of span. It then becomes:

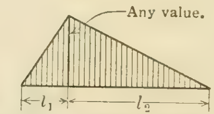
$$q = 5\,000 + 60\,000\,\frac{\sqrt{l_2}}{l_1 + l_2} \qquad (10)$$

which is the proposed loading formula.

Empirical formulas for equivalent uniform loads have been proposed in recent years, but they were deficient in one respect, namely, they expressed the equivalent uniform load as a function merely of the span without regard to the position of the member or section in the span.

Shorter Segment l_1 (columns); Longer Segment l_2 (rows)

l_2 \ l_1	0	10	20	30	40	50	60	70	80	90	100	120	140	160	180	200	220	240	260	280	300	400	500	600	700	800	900	1000
1000	6897	6878	6860	6840	6823	6807	6789	6772	6757	6740	6724	6694	6664	6635	6608	6580	6555	6530	6506	6481	6459	6355	6264	6185	6117	6053	5998	5948
900	7000	6978	6956	6934	6915	6894	6875	6855	6836	6818	6800	6763	6730	6698	6666	6636	6608	6579	6551	6525	6500	6385	6285	6200	6125	6059	6000	
800	7120	7095	7070	7045	7020	6997	6973	6950	6928	6907	6885	6845	6806	6768	6731	6697	6663	6632	6600	6570	6543	6415	6306	6212	6132	6060		
700	7268	7238	7205	7175	7145	7115	7090	7060	7030	7010	6985	6935	6890	6845	6805	6765	6725	6690	6655	6620	6590	6440	6325	6220	6135			
600	7450	7410	7370	7330	7295	7260	7225	7190	7160	7130	7100	7040	6985	6930	6885	6830	6790	6750	6710	6670	6630	6470	6335	6225				
500	7680	7630	7580	7530	7480	7440	7395	7350	7310	7270	7235	7160	7095	7030	6970	6915	6860	6810	6765	6720	6675	6490	6340					
400	8000	7925	7860	7790	7725	7665	7610	7550	7500	7450	7400	7310	7220	7140	7070	7000	6935	6875	6820	6765	6715	6600						
300	8460	8350	8245	8150	8055	7970	7885	7810	7735	7660	7600	7475	7360	7260	7165	7080	7000	6925	6855	6790	6730							
280	8580	8460	8340	8235	8135	8040	7950	7865	7785	7710	7640	7510	7390	7280	7180	7090	7010	6930	6860	6790								
260	8720	8580	8455	8335	8225	8120	8025	7930	7845	7765	7690	7545	7420	7305	7200	7100	7015	6935	6860									
240	8875	8720	8575	8410	8320	8200	8100	8000	7905	7815	7735	7580	7445	7325	7210	7110	7020	6935										
220	9045	8870	8705	8560	8420	8295	8180	8070	7965	7870	7780	7620	7470	7340	7225	7120	7020											
200	9240	9040	8860	8690	8535	8395	8260	8140	8030	7925	7830	7650	7495	7355	7230	7120												
180	9475	9240	9030	8835	8660	8500	8355	8220	8100	7980	7875	7685	7520	7370	7240													
160	9740	9460	9215	8995	8795	8615	8450	8300	8160	8035	7920	7710	7530	7370														
140	10 070	9730	9410	9175	8940	8735	8550	8380	8225	8085	7955	7730	7535															
120	10 480	10 055	9695	9380	9110	8865	8650	8460	8285	8130	7990	7740																
100	11 000	10 450	10 000	9615	9290	9000	8750	8530	8335	8160	8000																	
90	11 325	10 695	10 175	9745	9380	9065	8795	8560	8350	8160																		
80	11 710	10 960	10 365	9875	9470	9130	8830	8575	8350																			
70	12 170	11 270	10 575	10 020	9560	9150	8860	8585																				
60	12 740	11 640	10 800	10 160	9650	9220	8870																					
50	13 480	12 070	11 050	10 300	9710	9240																						
40	14 490	12 590	11 325	10 420	9745																							
30	15 960	13 220	11 570	10 475																								
20	18 420	13 940	11 710																									
10	23 970	14 480																										



Any Triangular Influence Line.

l_1 = Shorter Segment of Influence Triangle.
l_2 = Longer Segment of Influence Triangle.
q = Equivalent Uniform Load taken from Chart for the values of l_1 and l_2.
Values given in pounds per linear foot per track.

This table can be used for figuring the maximum stress in any member or section of any span. It gives stresses equal to (or slightly greater than) the maximum stresses producible by the heaviest existing locomotive loadings.

For Maximum Bending Moment at any section of any span. l_1 and l_2 = the two segments of the span.
$M = \frac{1}{2} \cdot q \cdot l_1 \cdot l_2$

For Maximum End Reaction or End Shear, $l_1 = 0$ and l_2 = the span.
$V = \frac{1}{2} \cdot q \cdot l_2$

For Maximum Shear at any section of a span, $l_1 = 0$. l_2 = the longer segment of the span and l = the span.
$V = \frac{1}{2} \cdot q \cdot l_2 \cdot \frac{l_2}{l}$

For Maximum Floorbeam Reaction or stress in Hanger, l_1 and l_2 = the adjoining panel lengths
$R = \frac{1}{2} \cdot q \cdot (l_1 + l_2)$

TABLE
OF
EQUIVALENT UNIFORM LOADS (PER TRACK)
FOR
DESIGNING RAILWAY BRIDGES

Based on Proposed Loading Formula M-60
$q = 5000 + 60\,000 \frac{\sqrt{l_2}}{l_1 + l_2}$

FIG. 11.

The proposed formula, notwithstanding its simplicity, makes full provision for the necessary variation of equivalent uniform load for different sections or members in the same span. For instance, in the case of a 100-ft. span, the proposed loading formula yields values of q varying from 9 240 for bending moments or flange stresses at mid-span, to 11 000 for flange stresses near the ends of the span; and from 11 000 for end shears to 13 480 for shears near mid-span; a total range of variation of 46 per cent. This variation corresponds to the actual stress-producing effects of locomotive loadings, and the reproduction of this appropriate variation of equivalent uniform loads within a given span is an important advantage of the proposed loading formula.

The possibility of fairly close representation of the equivalent uniform loads for all sections of all spans by a single formula is a point of superiority of the proposed Composite Standard over the Cooper engine loading.

The equivalent uniform loads yielded directly by the proposed loading formula for various sections of various spans are tabulated on Fig. 11. This tabulation can be incorporated in printed specifications to expedite the calculation of stresses based on the formula.

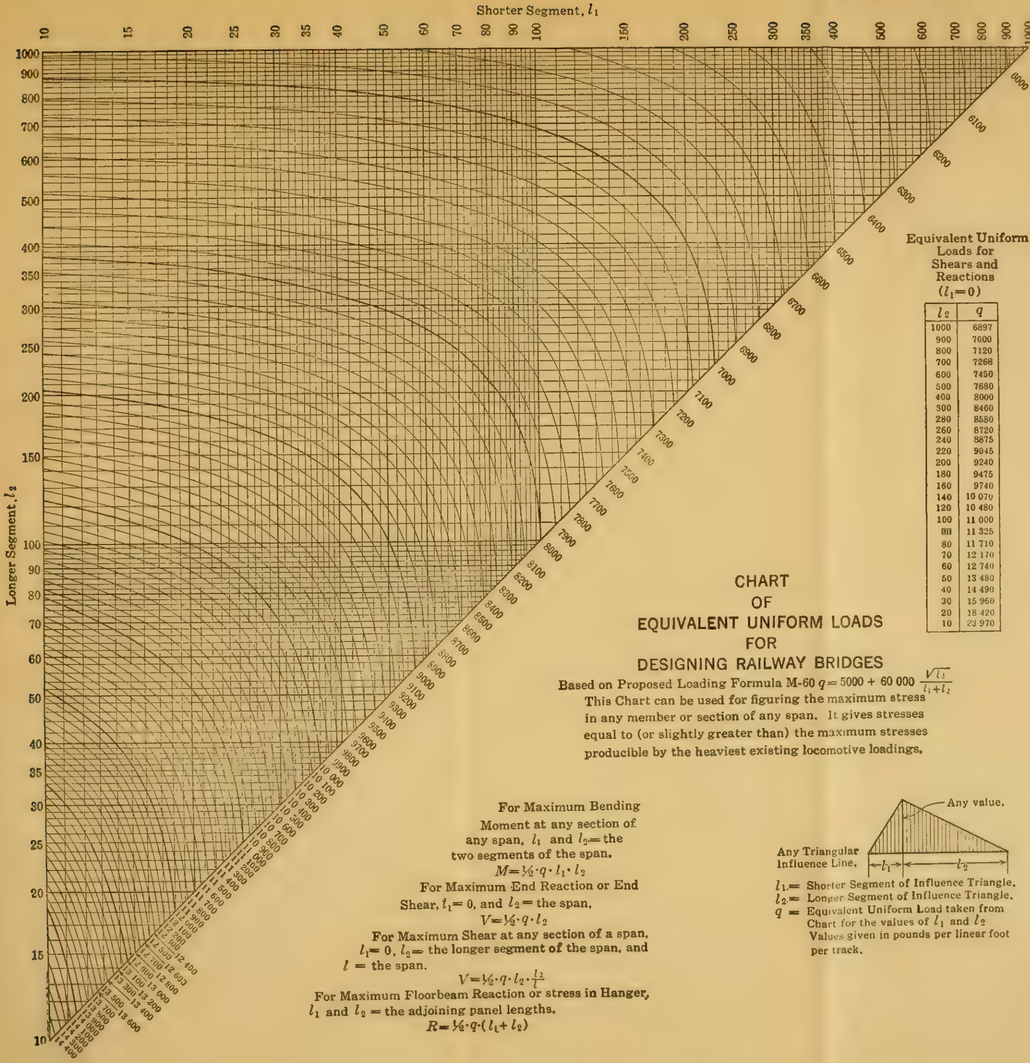
The tabulated values on Fig. 11 agree fairly well with those in the corresponding tables (Fig. 2 and Fig. 8) for the other proposed loadings. Except for only 4 or 5 values out of 405 in the table (Fig. 11), the values are on the safe side in comparison with the composite of the heaviest locomotives (Plate XII). Closer agreement could have been secured by adopting a formula with an odd decimal exponent; but it appeared preferable to keep the simpler expression, although it varied somewhat (on the side of safety) from the exact values desired.

Platting the values tabulated on Fig. 11, one obtains for the proposed loading formula, a chart of equivalent uniform loads (Plate XVIII). This chart, although yielding nearly the same values throughout as the similar preceding charts (Plates XIII and XVII), possesses a marked advantage in the perfect smoothness and systematic regularity of its curves. Since irregularities in a chart may be regarded as weak spots in the stress-producing effects of the corresponding loading specification, the ideal regularity of the curves in Plate XVIII constitutes a strong argument in favor of the proposed loading formula.

General instructions for the use of the chart are given on Plate XVIII. More complete directions for finding maximum stresses of all kinds are given on the similar chart for the Cooper loading, previously published by the writer, Plate XI.

A much simpler chart for the proposed loading formula is an isogonic diagram presented in Plate XIX. The equation between q, l_1, and l_2, is of such form as to permit a perfect nomographic solution of conventional form. A straight-line chart of this form, yielding exact values for the equivalent uniform loads, cannot be constructed for any loading specification consisting of a diagram of axle concentrations. The isogonic diagram, Plate XIX, is submitted merely as a suggestion. By varying the arrangement and scales of the three straight-line axes, other engineers can easily construct variations of this chart that may better suit their individual preference.

PLATE XVIII.
PAPERS, AM. SOC. C. E.
MAY, 1922.
STEINMAN ON
LOCOMOTIVE LOADINGS
FOR RAILWAY BRIDGES.



Equivalent Uniform
Loads for
Shears and
Reactions
$(l_1 = 0)$

l_2	q
1000	6897
900	7000
800	7120
700	7268
600	7450
500	7680
400	8000
300	8460
280	8580
260	8720
240	8875
220	9045
200	9240
180	9475
160	9740
140	10 070
120	10 480
100	11 000
[illegible]	11 325
80	11 710
70	12 170
60	12 740
50	13 480
40	14 490
30	15 960
20	18 420
10	23 970

CHART OF EQUIVALENT UNIFORM LOADS FOR DESIGNING RAILWAY BRIDGES

Based on Proposed Loading Formula M-60 $q = 5000 + 60\,000 \frac{\sqrt{l_2}}{l_1 + l_2}$

This Chart can be used for figuring the maximum stress in any member or section of any span. It gives stresses equal to (or slightly greater than) the maximum stresses producible by the heaviest existing locomotive loadings.

For Maximum Bending Moment at any section of any span, l_1 and l_2 = the two segments of the span.

$$M = \tfrac{1}{2} \cdot q \cdot l_1 \cdot l_2$$

For Maximum End Reaction or End Shear, $l_1 = 0$, and l_2 = the span,

$$V = \tfrac{1}{2} \cdot q \cdot l_2$$

For Maximum Shear at any section of a span, $l_1 = 0$, l_2 = the longer segment of the span, and l = the span.

$$V = \tfrac{1}{2} \cdot q \cdot l_2 \cdot \frac{l_2}{l}$$

For Maximum Floorbeam Reaction or stress in Hanger, l_1 and l_2 = the adjoining panel lengths.

$$R = \tfrac{1}{2} \cdot q \cdot (l_1 + l_2)$$

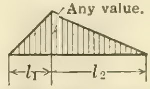
Any Triangular Influence Line.

l_1 = Shorter Segment of Influence Triangle.
l_2 = Longer Segment of Influence Triangle.
q = Equivalent Uniform Load taken from Chart for the values of l_1 and l_2. Values given in pounds per linear foot per track.

Equivalent Uniform Loads for Shears and Reactions
($l_1 = 0$)

l_2	1000	900	800	700	600	500	400	300	280	260	240	220	200	180	160	140	120	100	90	80	70	60	50	40	30	20	10
q	6897	7000	7120	7200	7450	7680	8000	8460	8580	8720	8875	9045	9240	9475	9740	10 070	10 480	11 000	11 325	11 710	12 170	12 740	13 480	14 490	15 960	18 420	23 970

This Chart can be used for figuring the maximum stress in any member or section of any span. It gives stresses equal to (or slightly greater than) the maximum stresses producible by the heaviest existing locomotive loadings.



l_1 = Shorter Segment of Influence Triangle.
l_2 = Longer Segment of Influence Triangle.
q = Equivalent Uniform Load taken from Chart for the values of l_1 and l_2
Values given in pounds per foot per track.

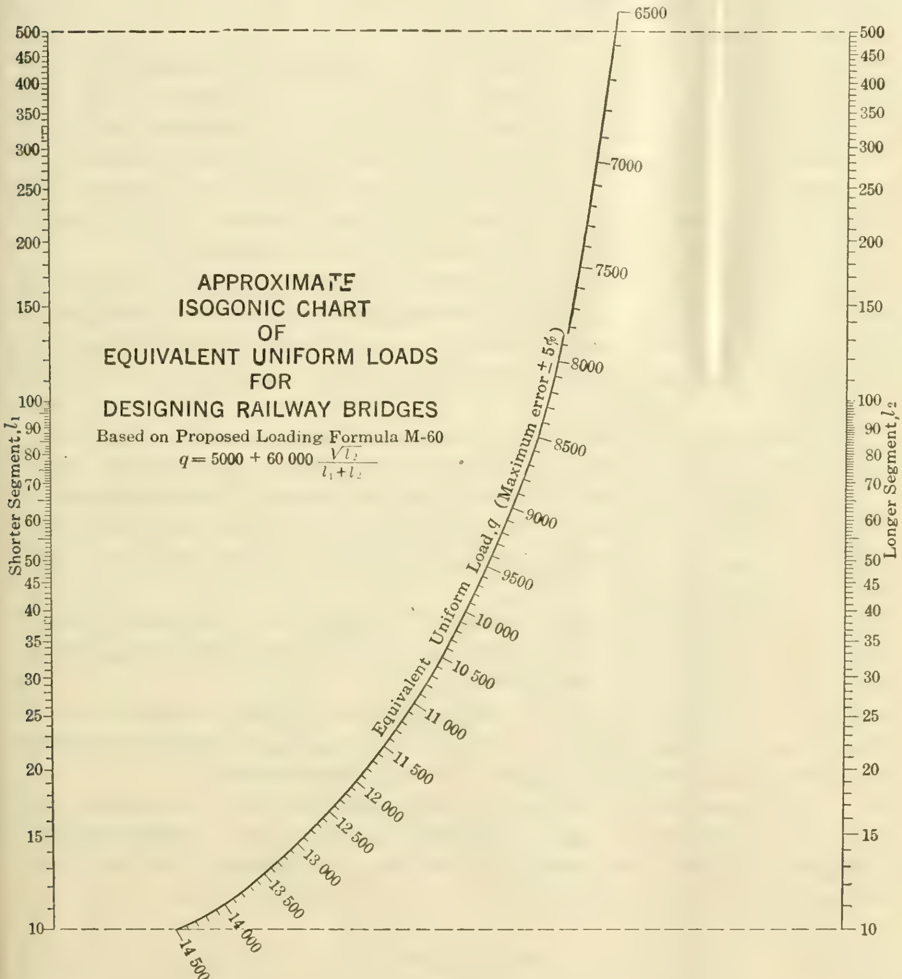


Fig. 12.

In the construction of the diagram, the values of span ($l_1 + l_2$) and longer segment (l_2) are platted on ordinary logarithmic scales. The q-axis is a similar logarithmic scale, except that the constant, 5 000, has been added to each numbering.

One drawback of this isogonic chart (Plate XIX) is the relatively small scale of the q-axis, which limits the precision attainable. The chart of curves, Plate XVIII, gives greater precision with equal, if not greater, expedition.

To overcome objections arising from the crowding of the graduations near one end of the q-axis in the exact nomographic diagram (Plate XIX), there is presented in Fig. 12 an isogonic chart of a more convenient form constructed for the same loading. This is an empirical and, therefore, slightly approximate, isogonic diagram of the type devised by the writer and previously described in connection with Fig. 5.

The smoothness and simplicity of this approximate nomographic chart (Fig. 12) for the proposed loading formula are unattainable with any other loading specification considered in this paper. The accuracy attainable is sufficient for most practical purposes, the greatest errors being less than $\pm$ 4 or 5 per cent. This chart can be easily reproduced and incorporated in any printed specifications based on the proposed loading formula. For the Cooper loading, a chart of this form is practically out of the question.

Moment and shear graphs are presented in Fig. 13 for the purpose of comparing the proposed loading formula with existing loadings. These graphs show that the proposed loading formula is a much closer and safer representation of the composite of the heaviest locomotives than the present Cooper loading.

For end shears, the graph for the proposed loading formula follows fairly close to the Composite Standard, with all variations on the side of safety.

For mid-span moments, the graph for the proposed loading formula is again a fairly close approximation to the Composite Standard, with a deficiency of only a few per cent. at short spans and a small variation on the safe side at long spans.

For stresses at intermediate sections of a span, the variations from the Composite Standard will be intermediate between the corresponding variations for end shears and center moments.

The moment and shear graphs for the proposed loading formula shown in Fig. 13 are obviously smoother curves than are attainable with any loading specification consisting of a diagram of wheel concentrations.

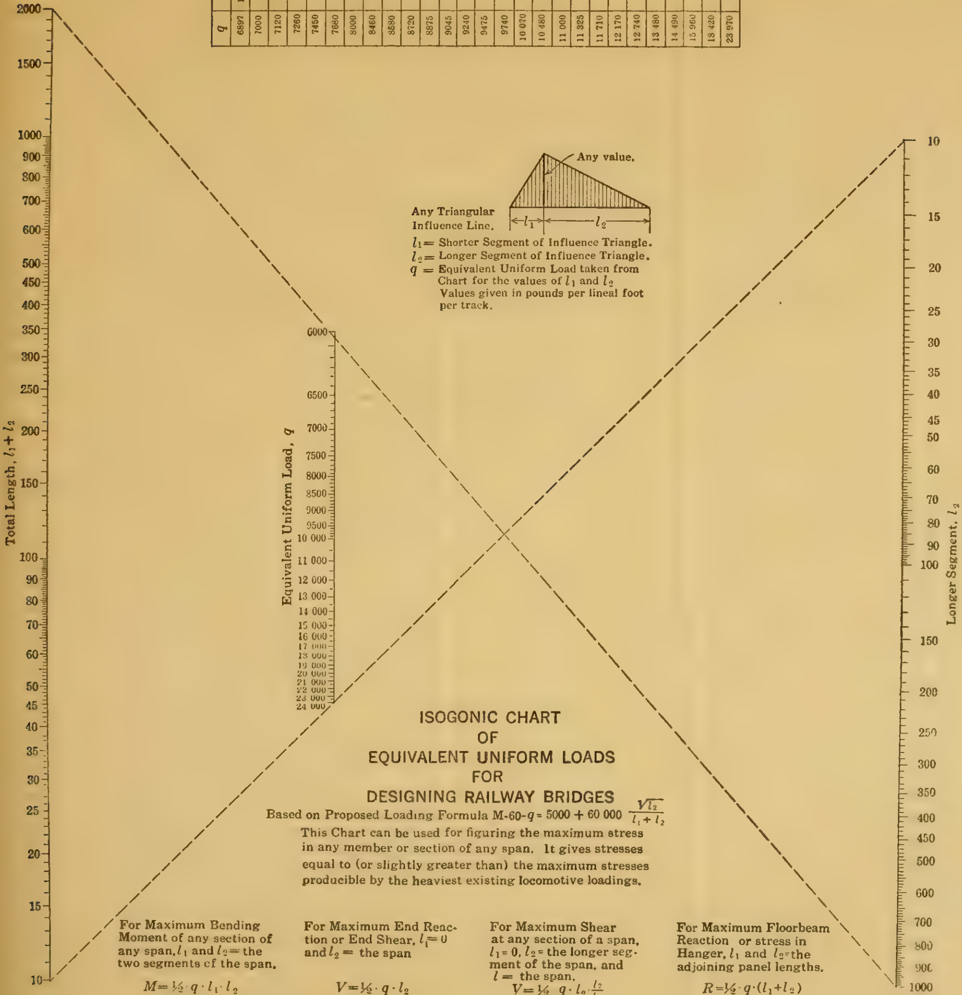
Fig. 14 shows how a system of loading classes similar to the Cooper system can be constructed from the proposed loading formula. Designating the intensity of loading corresponding to the formula as derived from the Composite Standard as M-60, the unit base, or M-10 loading, becomes:

$$q = 833 + 10\,000 \frac{\sqrt{l_2}}{l_1 + l_2} \qquad (11)$$

Multiplying this loading by the constants 4, 5, 6, etc., the successive classes, M-40, M-50, M-60, etc., are obtained.

Equivalent Uniform Loads for Shears and Reactions
($l_1 = 0$)

l_2	q
1000	6897
900	7000
800	7120
700	7260
600	7450
500	7680
400	8000
300	8460
280	8580
260	8720
240	8875
220	9045
200	9240
180	9475
160	9740
140	10 070
120	10 480
100	11 000
90	11 325
80	11 710
70	12 170
60	12 740
50	13 480
40	14 490
30	15 960
20	18 420
10	23 970



l_1 = Shorter Segment of Influence Triangle.
l_2 = Longer Segment of Influence Triangle.
q = Equivalent Uniform Load taken from Chart for the values of l_1 and l_2. Values given in pounds per lineal foot per track.

ISOGONIC CHART OF EQUIVALENT UNIFORM LOADS FOR DESIGNING RAILWAY BRIDGES

Based on Proposed Loading Formula M-60-$q = 5000 + 60\,000\,\dfrac{\sqrt{l_2}}{l_1 + l_2}$

This Chart can be used for figuring the maximum stress in any member or section of any span. It gives stresses equal to (or slightly greater than) the maximum stresses producible by the heaviest existing locomotive loadings.

For Maximum Bending Moment of any section of any span, l_1 and l_2 = the two segments of the span.

$M = \tfrac{1}{2} \cdot q \cdot l_1 \cdot l_2$

For Maximum End Reaction or End Shear, $l_1 = 0$ and l_2 = the span

$V = \tfrac{1}{2} \cdot q \cdot l_2$

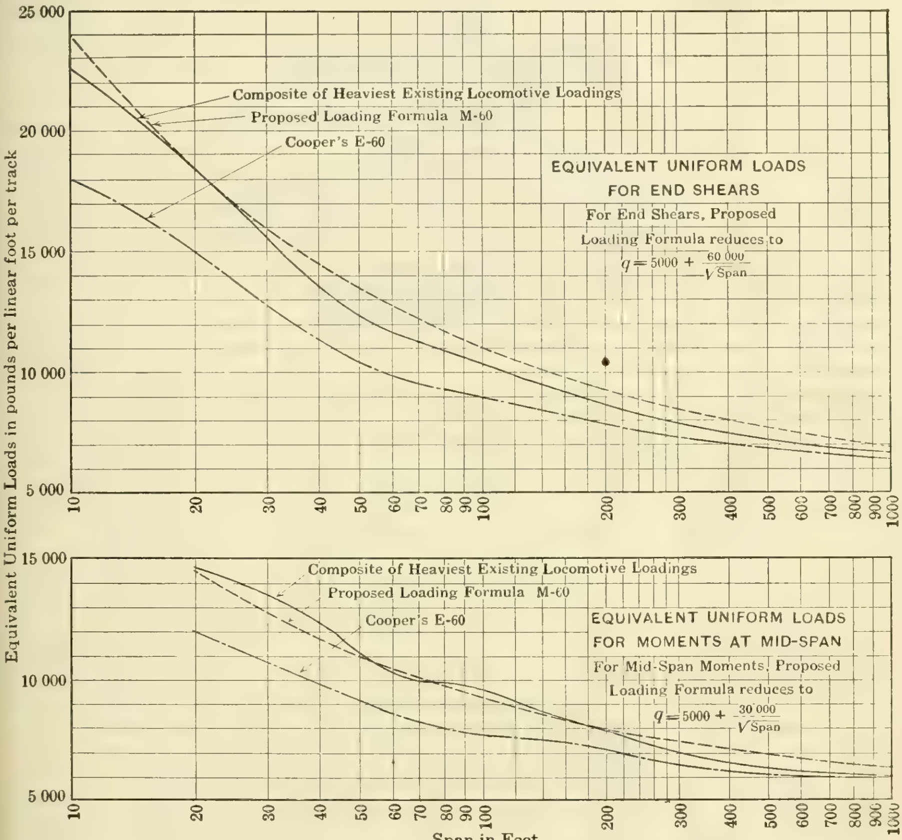
For Maximum Shear at any section of a span, $l_1 = 0$, l_2 = the longer segment of the span, and l = the span.

$V = \tfrac{1}{2}\ q \cdot l_2 \cdot \frac{l_2}{l}$

For Maximum Floorbeam Reaction or stress in Hanger, l_1 and l_2 = the adjoining panel lengths.

$R = \tfrac{1}{2} \cdot q \cdot (l_1 + l_2)$

Loading M-60 will give stresses for all spans equal to or slightly greater than the maximum stresses producible by the heaviest existing locomotives. To provide for a future increase of 25%, it is suggested that specifications recommend Loading M-50 with provision in the design for a 50% overload, or Loading M-60 with a provision for a 25% overload.



COMPARISON OF PROPOSED LOADING FORMULA
WITH EXISTING LOADINGS
Proposed Loading Formula M-60

$$q = 5000 + 60\,000 \frac{\sqrt{l_2}}{l_1 \; l_2}$$

l_1 = Shorter Segment of Influence Triangle.
l_2 = Longer Segment of Influence Triangle.
q = Equivalent Uniform Load

FIG. 13.

CONCLUSION

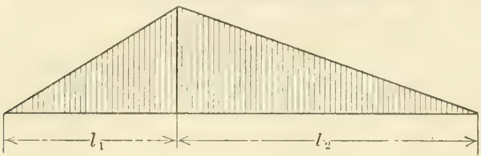
After showing the inadequacy of the Cooper system to represent modern loading conditions properly, the writer has constructed a Composite Standard covering the stress-producing effects of the heaviest existing locomotives and has then devised three alternative forms of specification conforming to this Composite Standard.

The advantages over the Cooper system of any loading specification based on the Composite Standard are:

1.—The proposed specification makes it possible to design bridges strong enough in all their parts, without waste, for the heaviest existing locomotive loadings, without requiring separate computations for each loading.

2.—The proposed specification gives bridges of uniform strength in all

PROPOSED LOADING FORMULA
FOR EQUIVALENT UNIFORM LOADS
FOR DESIGN OF RAILWAY BRIDGES



l_1 = Shorter segment of Influence Triangle
l_2 = Longer segment of Influence Triangle
q = Equivalent Uniform Load for the values of l_1 and l_2

M-10	$q = 833 + 10\,000 \dfrac{\sqrt{l_2}}{l_1 + l_2}$
M-40	$q = 3333 + 40\,000 \dfrac{\sqrt{l_2}}{l_1 + l_2}$
M-50	$q = 4166 + 50\,000 \dfrac{\sqrt{l_2}}{l_1 + l_2}$
M-60	$q = \mathbf{5000} + \mathbf{60\,000} \dfrac{\sqrt{l_2}}{l_1 + l_2}$
M-70	$q = 5833 + 70\,000 \dfrac{\sqrt{l_2}}{l_1 + l_2}$
M-80	$q = 6666 + 80\,000 \dfrac{\sqrt{l_2}}{l_1 + l_2}$
M-90	$q = 7500 + 90\,000 \dfrac{\sqrt{l_2}}{l_1 + l_2}$

Loading M-60 will give stresses for all spans very close to the maximum stresses producible by the heaviest existing locomotive loadings. It is approximately equivalent to Cooper's E-75 for short spans and to Cooper's E-60 for long spans

Fig. 14.

their parts for present and prospective future loadings, without requiring different load ratings for different members in a span.

3.—The proposed specification gives designs of uniform strength for bridges of all spans under present and prospective future loadings, without requiring different load ratings for different lengths of span.

4.—The proposed specification, being based on the heaviest modern locomotives and train loads, better represents the future development to be expected in loadings than a specification based on the engines and train loads of thirty years ago.

In addition, the proposed specification, in the three forms presented by the writer, offers advantages over the Cooper loading in simplicity, regularity, ease of computation, and greater facility of diagrammatic representation.

Of the three alternative forms developed in this paper for the proposed new specification, each has distinctive features to recommend it:

1.—The proposed loading diagram represents the smallest departure from present methods, involving merely the substitution of a new and simpler wheel-load diagram for the one now in use. It will best meet the requirements of engineers who prefer a concrete picture of a locomotive as a loading specification. Furthermore, it affords the closest agreement throughout the entire range of spans with the composite of the heaviest existing locomotives.

2.—The proposed simplified loading greatly reduces the time and labor of calculating stresses. It is a greatly simplified loading which can be handled expeditiously without tables or charts.

3.—The proposed loading formula is an ideal, scientific form of loading specification. It is the most convenient in application; it yields tables, diagrams, and charts of unequalled simplicity and regularity; or, if tables and charts are not at hand, any maximum stress can be found by a simple operation on the ordinary slide-rule. It is a "short-cut" specification, virtually prescribing stresses rather than loads.

If this paper only serves to direct attention to the inadequacy of existing loading specifications, and to indicate the general lines of attack in determining a new specification to be adopted, the writer will feel repaid for the labor expended.

received scant attention. The study of the transmission of lateral earth pressure is an offshoot from the general problem. It has received more attention than the general problem, but, as the writer has pointed out,* its solution, as far as rigor and exactness of formulation are concerned, is comparatively unimportant, and existing data and formulas suffice for a proper design of structures built to sustain lateral soil thrusts. For this reason, the phenomena attendant on lateral pressures, as far as the ordinary granular theories apply, is not a part of the subject of this paper and restriction is made, generally speaking, to the transmission of vertically applied loadings.

The transmission of pressure through solids, although superficially an easy problem to analyze, is one that involves great mathematical difficulties. For this reason, specific problems are generally not analyzed, a few "rule-of-thumb" methods sufficing to indicate the distribution of stress through the material in question.

The problem of the distribution of stress under a single concentrated load applied to a plane boundary of an otherwise infinitely dimensioned solid has received complete study by Boussinesq. The method of investigation follows the scheme of solution given in his book on the applications of the potential. Love has given a résumé of the methods in his treatise on the mathematical theory of elasticity. Boussinesq has given general expressions for the extension of the results to various types of surface loadings. The expressions are not simple to use or to interpret, and the devices used in this paper seem to lend themselves better to practical study. Professor Horace Lamb† has given expressions for stress distribution under like types of loadings, but the results involve the use of the Bessel Functions and, therefore, require extensive tables for application.

A fairly rigorous solution of the problem should indicate the correct paths of the stress and strain systems, perhaps only qualitatively, and thus aid in securing a better understanding of what takes place in foundations and possibly secure a working clue to the phenomena attendant on earth pressure and its distribution.

The inclusion of the study of earth pressure phenomena with general elastic solid phenomena is made justifiable, through the results of recent research. The element of coherence appears to lend quasi-elastic properties to soil. Although it may seem far-fetched to apply elastic theory to a material possessing finite voids with consequent large discontinuities, yet experimental data seem to indicate that the coherent soil does acquire sufficient elastic properties to make it act, in some ways, like an elastic solid. Thus‡:

"* * * Practically all soils possess elastic properties, the amount depending on the character and quantity of the cementing material giving it cohesion and the water content. If unequal loads per unit of area are placed on such soil, unequal settlements will take place. The soil, however, will recover on the removal of the loads unless the latter are great enough to over-

* "Effect of Practical Factors on Earth Pressure Theory", *Engineering-News Record*, Vol. 86, p. 682.

† *Proceedings*, London Mathematical Soc., Vol. 34, p. 276.

‡ Progress Report of the Special Committee to Codify Present Practice on the Bearing Value of Soils for Foundations, etc., *Proceedings*, Am. Soc. C. E., Vol. XLVI (August, 1920), p. 909.

come its elastic properties, by breaking down its cohesion. Such action is most apparent at some depth beneath the surface, as the displacement is retarded by the restraining action of the surrounding soil. This unequal settlement, though slight, may be sufficient with certain soils and structures to cause trouble.

"As evidence of such action the rebound, or rising, after releasing the jacks, of piles forced into the soil by direct pressure, may be mentioned. The action is also apparent on releasing jacks and wedges when cribwork is used in temporarily supporting heavy loads, as in the underpinning of buildings, etc."

At the conclusion of a discussion on earth-pressure theories* it was noted: "These facts indicate the existence of relations between stress and strain in sands similar to those which are known to exist for solid bodies."

The writer has previously pointed out† that the distribution of pressure as experimentally determined by Professor M. L. Enger‡ seems to follow almost the identical law of transmission of stress, as determined from the mathematical theory of elasticity. Whether the soils actually possess elastic properties making them amenable to the mathematical theory of elasticity, is not a matter of importance as long as it is conceded that they behave in a manner similar to elastic bodies as far as the transmission of pressure is affected.§

The general theory of the transmission of stress through a solid does not lead to simple solutions of usable value. However, if in place of dealing with a solid of three dimensions, a plane section is taken as typifying the stress and strain condition, it is possible to obtain usable solutions. It must be emphasized that, at present, rigorous results or exact formulas are out of the question. All that is sought is a suggested trace of the transmission of pressure. Fortunately, this specific problem, that of the transmission of pressure through a solid, is substantially solved for the engineer's purpose when qualitative results are indicated.

This paper is confined to the discussion of two cases:

Case I.—The transmission of pressure through a solid or through a coherent soil, under an applied vertical loading.

Case II.—The transmission of pressure through a solid subjected to stresses produced by its own weight.

Utilizing the elastic analogy as pointed out, application will be made under Case I to the transmission of pressure through soil foundations and under Case II to the general distribution of pressure through earth masses, rock, and other soils.

Case I

The analysis of the infinitesimal displacements and stresses to which an element of a body is subjected when a given force system is applied

* "Old Earth Pressure Theories and New Test Results", by Dr. Charles Terzaghi, *Engineering News-Record,* Vol. 85, p. 632.

† "Retaining Walls: Their Design and Construction", p. 31.

‡ *Engineering Record,* Vol. 73, p. 106.

§ The application to bodies not possessing isotropic properties is indicated by the following remarks of J. H. Michell (*Proceedings,* London Mathematical Soc., Vol. 32, p. 256): "It appears, therefore, that the law of depression is the same as for an isotropic solid; consequently, the applications of the law, which were made by Boussinesq and Hertz, to problems concerning isotropic bodies in contact, may be at once extended to ælotropic solids here considered, with the limitation that the normal to the plane of contact must be an axis of elastic symmetry."

at the surface of the body, leads to the establishment of several differential equations containing the displacements or the stresses as unknowns. For the purposes of this paper it is not necessary to burden the reader with the development of these equations, which, to those interested, may be found in any standard treatise on elasticity.* The general theory of their solution involves considerable analysis, but with restrictions, as noted subsequently, a solution may be found by following a theorem of Michell. When the stress analysis is confined to the discussion of the stress system in a plane section of the body, it is possible to reduce the general equations of elasticity to a simple form, involving one unknown, termed a stress function. The displacements are the differential coefficients of the stress function, and the stresses may be expressed in terms of the displacements. The problem is to find the form of the stress function, which satisfies the differential equation and leads to proper values at the boundary. Michell† has found the form of the stress function for the case of a uniformly distributed loading along a part of the top of the plane (the type of loading covered under Case I).

The general equation of elasticity for a solid, when it is subject only to loadings applied externally, is of the form:

$$\frac{d^4 F}{d\ x^4} + \frac{2\ d^4 F}{d\ x^2\ d\ y^2} + \frac{d^4 F}{d\ y^4} = 0$$

where F is known as the stress function. The stresses are found from the solution of this equation and lead finally (expressed in polar co-ordinates) to the form:

$$P = \frac{1}{r^2}\frac{d^2 F}{d\ \theta^2} + \frac{1}{r}\frac{d\ F}{d\ r};\ Q = \frac{d^2 F}{d\ r^2};\ U = -\frac{d}{d\ r}\left(\frac{1}{r}\frac{d\ F}{d\ \theta}\right)$$

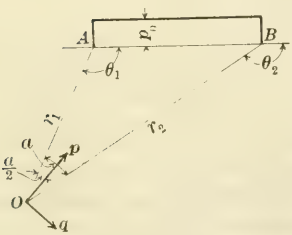


FIG. 1.

A form of the stress function may be found by inspection. Referring to Fig. 1, the point O is referenced to each of the terminals of the loading, A and B, by a separate co-ordinate system. If the stress function is assumed to be of the form,

$$F = r_1^2\ \theta_1 - r_2^2\ \theta_2$$

the stresses may be assumed as being made up of two parts: The derivatives with respect to the origin at A giving one set of partial stress values, and the derivatives with respect to the co-ordinates of the other terminal giving another partial set; the sum of the two sets giving the total stress value at the point, O. Thus, with respect to the origin at A:

$$P = 2\ \theta_1;\ Q = 2\ \theta_1;\ U = -1$$

and with respect to the origin at B:

$$P' = -2\ \theta_2;\ Q' = -2\ \theta_2;\ U' = +1$$

* "A Mathematical Treatise on the Theory of Elasticity", by A. E. H. Love; or in the Appendix of "The Elasticity and Resistance of Materials", by W. H. Burr.

† *Proceedings*, London Mathematical Soc., Vols. 31, 32, and 34. For the theorem established on the following pages see especially Vol. 34.

To find the principal stresses at the given point, O, proceed as follows: Assume that the present axes are turned through the angle, ϕ. By the standard theorems for the transformation of stress axes* the stresses, P'', Q'', and U'' (these stresses are normal to the new axes), are related to the stresses referred to the original axes, as follows:

$$P'' = l_1^2\, P + m_1^2\, Q + 2\, l_1\, m_1\, U$$
$$Q'' = l_2^2\, P + m_2^2\, Q + 2\, l_2\, m_2\, U$$
$$U'' = l_1\, l_2\, P + m_1\, m_2\, Q + (l_1\, m_2 + l_2\, m_1)\, U$$

where l and m represent the direction cosines (the cosine of the angle that a line makes with a given axis is termed a direction cosine of that line) of the new axes with respect to the old. The direction cosines have the following values:

$$l_1 = -\, m_2 = \sin \phi;$$
$$l_2 = \quad m_1 = \cos \phi.$$

Introducing these values in the trasformation equations, previously mentioned, and combining the equations by addition and subtraction, the following relations are found:

$$P'' + Q'' = P + Q$$
$$P'' - Q'' = -\,(P - Q)\cos 2\,\phi + 2\,U \sin 2\,\phi$$
$$2\,U'' = \quad (P - Q)\sin 2\,\phi + 2\,U \cos 2\,\phi$$

These equations may be reduced to a much simpler form if the equation,

$$e^{i\phi} = \cos\phi + i \sin\phi$$

is borne in mind. i has the usual significance as the square root of -1 and e is the exponential base. With this relation, the transformation equations may be expressed as,

$$P'' - Q'' - 2\,i\,U'' = e^{2i\phi}\,(Q - P - 2\,i\,U)$$

These are the general equations of a stress transformation. Now, give the axis of transformation a definite turn so that the axes of stress are the bisectors of the angle, a, as shown in Fig. 1. The stress components are again separated into two parts, referring, in turn, to either origin, A or B.

For Origin A, the axes may be considered to have been turned the amount, $\frac{a}{2}$ and for Origin B, the axes may be considered to have been turned the amount, $-\frac{a}{2}$. Denote the total stresses referred to the new axes as p, q, and u, respectively. These stresses are then compounded of the two transformed stress systems, as previously found, substituting, respectively, $+\frac{a}{2}$ and $-\frac{a}{2}$, for the angle, ϕ. Two equations are then found as follows:

$$p + q = P + Q + P' + Q' = 4\,(\theta_1 - \theta_2) = -\,4\,a$$
$$p - q - 2\,i\,u = e^{ia}\,(Q - P - 2\,i\,U) + e^{-ia}\,(Q' - P' - 2\,i\,U')$$
$$= 2\,i\,(e^{ia} - e^{-ia})$$

* "A Treatise on the Mathematical Theory of Elasticity", by A. E. H. Love, 1st Edition, p. 62.

or, since,

$$\sin a = \frac{1}{2} (e^{ia} - e^{-ia})\, i$$

the expression becomes equal to $-4 \sin a$, and, finally, u is zero, showing that only normal stresses exist on the axes and that these are, therefore, the principal stresses at the point, O. The principal stresses have the values:

$$p = -2 (a + \sin a)$$

$$q = -2 (a - \sin a)$$

It is noted that when the points are on the plane boundary, the principal stress reduces to a normal pressure of 2π, and account must be taken of this relation in reducing the forms to take care of any value of the surface loading.

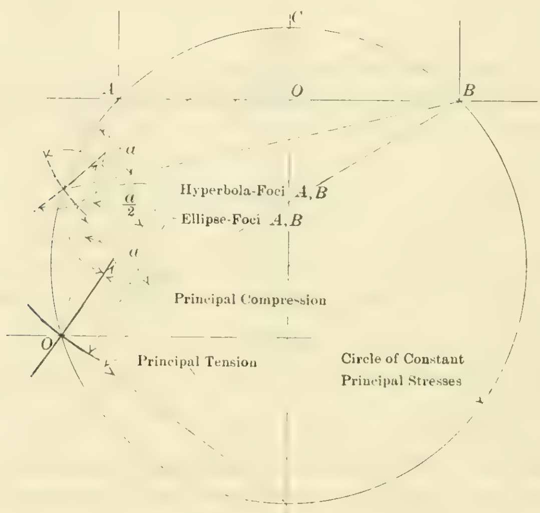


FIG. 2.

In the general analysis, the selection of the signs does not affect the validity of the result, and as it is apparent by inspection that the principal intensities must be of opposite sign, the character of the principal stress has been chosen with the signs as noted subsequently. To reduce the equations to a form satisfying a uniform loading of p_0 per unit of length between the points, A and B, a simple substitution gives the following forms for the principal stresses:

$$p = \frac{p_0}{\pi} (a + \sin a)$$

$$q = -\frac{p_0}{\pi} (a - \sin a)$$

From these simple relations, a number of important corollaries are found. Referring to Fig. 2: A circle passing through the point, O, and the termini of the load line, A and B, is the locus of constant values of the angle, a, that

is, every point on this line has the same value of the angle, a. Therefore, this circle is the locus of equal values of the principal stresses, p and q. From the properties of the circle, it is seen that the principal stresses are directed toward the upper and the lower extremities of the vertical diameter.

Conics which have the same foci are termed confocal conics. From the properties already noted, it is seen (the proof is not difficult) that, at any point in the body, the principal stresses are found in direction by the intersection of two confocal conics passing through the point, the foci being the termini of the loads, A and B. The principal compressive stresses are along ellipses and the principal tension stresses along hyperbolas. Confocal conics always intersect orthogonally, that is, at right angles to each other. In a material weak in tension, the curves of possible failure are the hyperbolas, and the tension stresses are normal to these curves. That the surfaces of failure are of this character in deep rock cuts has been noted by H. G. Moulton,* M. Am. Soc. C. E., and also in illustrations of the paper of Professor Enger, previously mentioned, in which the stress paths are seen to follow along curves hyperbolic in shape. (See, especially, the movement under an 8-in. block.)

From the intersection of the circles of uniform stress with the confocal conics, the rate of change of the principal stresses along each conic may be noted. (See Fig. 3.)

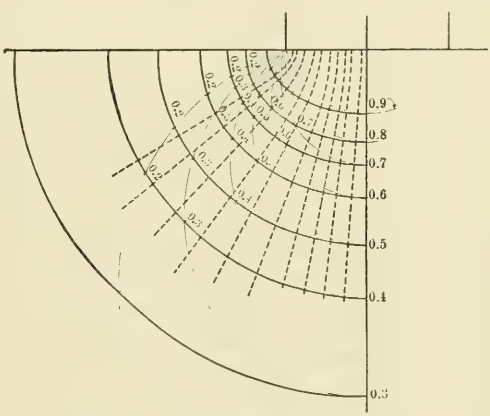


FIG. 3.

It is probably of most importance to note the distribution of pressure along the horizontal planes. As given, the equations are not in form for ready use, and it is necessary to resolve them into the vertical and horizontal components. (See Fig. 4.)

Let ϕ be the angle that the principal compression stress, p, makes with the horizontal. Then, the vertical component is found from the equation:

$$p_y = p \sin \phi - q \cos \phi$$

For simplicity of expression, and as only comparative studies are required, it will be assumed that the intensity of loading along the surface is unity, and that the loaded length extends unit distance either side of the y-axis.

* "Earth and Rock Pressures", *Transactions*, Am. Inst. of Mining and Metallurgical Engrs., Vol. 63 (1920), p. 327.

Using the values of p and q, as previously found, with the value of the load as unity, the last expression takes the form:

$$p_y = \frac{a\,(\sin \phi - \cos \phi) + \sin a\,(\sin \phi + \cos \phi)}{\pi}$$

From Fig. 4, remembering that c is one,

$$\tan \phi = \frac{y + \tan \frac{a}{2}}{x}$$

Substituting this value in the latter expression, there is found:

$$p_y = \frac{a\left(y + \tan \frac{a}{2} - x\right) + \sin a\left(y + \tan \frac{a}{2} + x\right)}{\pi \sqrt{x^2 + \left(y + \tan \frac{a}{2}\right)^2}}$$

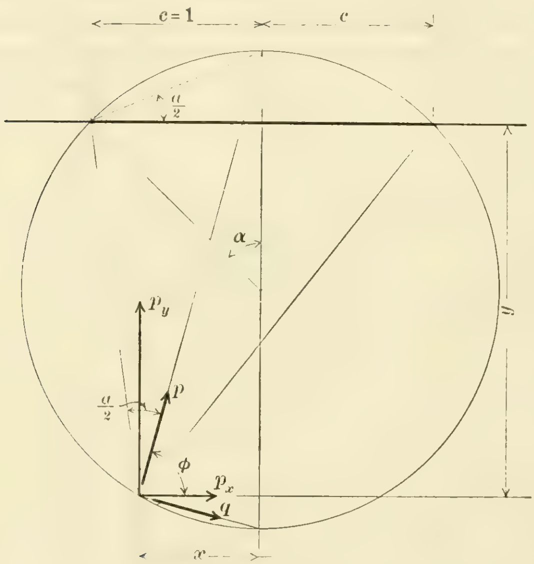


Fig. 4.

To obtain the relation between the angle, a, and the co-ordinates, x and y, let R be the radius of the circle. Then,

$$R^2 = x^2 + (y - \cot a)^2$$

and, since c is one,

$$R^2 = 1 + \cot^2 a$$

and a is found from the equation,

$$\cot a = \frac{x^2 + y^2 - 1}{2\,y}$$

Fig. 5 illustrates the distribution of pressure at the various horizontal planes when the surface is loaded with a unit intensity per unit length, one unit length being loaded with side of the y-axis. The intensities of pressure

are in decimals of a unit and to apply to any actual condition of loading, the skeleton intensity diagram is multiplied by the actual surface intensity of loading.

Before analyzing these results, a review of existing methods may be presented. Ordinary practice assumes a uniform distribution of pressure along any horizontal plane below the loaded surface, increasing in spread as the distance below the surface increases and confined, roughly, within planes making an angle of 45° with the vertical; that is, pressure is assumed to distribute itself along a 1 : 1 slope. Lacher* has given the following expression for the vertical live load intensity at any depth, h, below the surface (due to locomotive wheel loads):

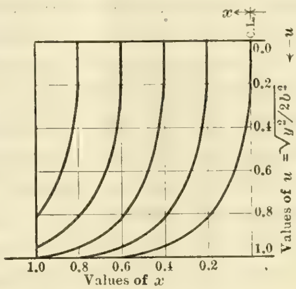


FIG. 5.

$$p = \frac{11\,000}{(8 + 2\,h\,x)}$$

where x is the inclination of the spread planes, in fractions of a foot per foot of depth. Recently, experimental data have illustrated in better fashion the distribution of stress through a foundation. The progress reports of the Special Committees on the Bearing Value of Soils for Foundations and on Stresses in Railroad Track, of the Society, have shown graphically the actual loading conditions, as determined by the Goldbeck strain gauge. It is clear that data in general on such stress distribution are meager and that engineering design has followed traditionary measures for such computations as were deemed to be necessary, rather than to attempt methods of rational analysis.

Referring to Fig. 5, it may be noted that the stress distribution across any horizontal plane is not uniform, but has a maximum at the center and diminishes in intensity as the distance from the central axis increases. This has been demonstrated by the other theorems of elasticity; the "simple solution" method of Boussinesq, to which reference has already been made, leads to a similar distribution of stress. The strain-gauge readings of the experiments of the Special Committees of the Society previously referred to, show the same characteristic loading.

Averaging the intensities of load on the several planes, it is seen that a 1:1 slope gives a reasonable distribution of pressure, if the effects of unequal loading are ignored. To this extent, the "rule-of-thumb" method previously quoted is correct. It is noted, however, that the limiting zone of pressure influence is contained within a 1:2 slope. The formulas, as given, involve no elastic constants and with the reservation previously made, the results may be extended to coherent soils. With the limiting zone of surface-pressure influence in mind, it is seen that the usual criterion of a 1:1 slope is not always safe to follow in determining loads on sub-surface structures, or in the question of underpinning and shoring structures adjacent to or contained within such zones. The theorems just established and the figures based

* *Journal*, Western Soc. of Engrs., Vol. 20.

on them are predicated on a plane extending indefinitely in both directions. If the horizontal distances are finite, as they usually are in engineering structures, the curves will probably be modified. It is recognized, however, that such modification will not materially affect the qualitative results already given and, within reasonable distances away from the applied loading, the zones of influence are shown with a fair degree of accuracy.

A study of the expression for q, the principal tension, shows that for distances close to the origin and to the surface of loading, a is equal to 180° and as sin a is zero, the tensile stresses are a maximum and a tendency to split along the hyperbolas should be found. The material adjacent to the applied loading and outside the zone of influence has an inhibiting effect on the tension, but this restraining effect decreases as the distance from the surface increases. Thus, although the maximum tension stress is indicated close to the surface, the uncompensated stresses farther away, along the hyperbolas, may produce dangerous stresses.

Quoting from the Progress Report* of the Special Committee on the Bearing Value of Soils for Foundations, etc.:

"* * * In the case of an elastic solid the outer region of pressure and tension contributes to the distribution of stress, while in the case of soils, which cannot support tension in any marked degree, the surface between these regions presents a surface of discontinuity of strain resulting in a greater concentration of stress within the compression cone. This cone, of course, will have different angles for different types of materials, but it is probable that it will not differ widely in ordinary soils."

The "cone" of compression, as noted in the report of the Special Committee, may be compared to the zone of the transmission of average pressure, with which it roughly coincides.†

Further reference may be made to the Progress Report of the Special Committee on Stresses in Railroad Track,‡ in which a study is had of the transmission of pressure through granular materials. There is a general qualitative agreement in the manner of the distribution of the pressure along horizontal planes, and it is probable that, if an equation for the location of equal vertical loads was derived, it would be found that the coherent and the elastic solids have the same type of "bulb" curves as the granular solids.

The agreement in stress distribution between material of so varied a character as that covered in the various reports mentioned, as well as the elastic solids discussed in this paper, seem to indicate that stress distribution under a surface loading follows a simple general law of distribution, regardless of the character of the material.

As long as emphasis is placed on the qualitative worth only of the results of the theorem of Michell, the previously mentioned conclusions may prove of service. It seems hardly necessary to point out that the actual stress values cannot possess great validity, the further the material under discussion de-

* *Proceedings*, Am. Soc. C. E., August, 1920, p. 933.

† In the text by Love, previously mentioned, the surface of discontinuity between displacements from and to the central axis is also a cone, the angle of divergence of which, for an isotropic solid, is roughly 68°, that is, the sides of the triangle make an angle of about 32° with the vertical.

‡ *Transactions*, Am. Soc. C. E., Vol. LXXXIII (1919–20), p. 1409.

parts from the isotropic properties of the solids on which the theory of elasticity has been predicated. Qualitatively, the 1:1 slope has been shown to be a reasonable assumption for the distribution of stress through a mass, although the maximum intensity of pressure is greater than the average, and soil conditions may be such that this latter condition will control the proper layout of the footing. The fact that the ground may heave adjoining a heavy concentration on fairly soft bottoms, may tend to dissipate some of the inequality of the loading, but the distribution, as indicated in Fig. 5, is worthy of careful study.

Case II

Referring to Fig. 6, there is a typical case of a block of material of any character subjected to the forces produced by its own weight. The dimensions of the block may be assumed to be large, so that application may be made to deep rock cuts and to the action of coherent earths. Again, the quasi-elastic properties of such soils may be utilized in developing the equations for the distortions which the mass suffers under the body forces.

The analysis of this material is comparatively simple, following the analysis of a similar problem by Love,* who has analyzed the case of a hanging body suspended to an infinite solid. The present problem is merely the converse of this case.

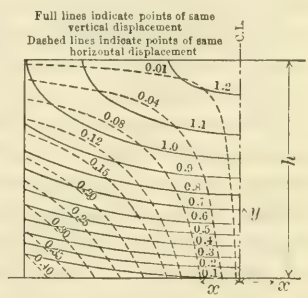


Fig. 6.

The only force acting on any element is the weight of the material above it. If the y-axis is measured from the surface and the unit weight of the material is w, the vertical force on the elementary prism is $w\,y$. As the extension is proportional to the force, the extension in the vertical direction becomes $\frac{w\,y}{E}$, in which E is the modulus of extension for the material. If the ratio of lateral to vertical extension is termed K (the usual Poisson ratio), then the lateral extension is $\frac{K\,w\,y}{E}$. These two relations are the foundation equations on which the general stress equations are based, and the differential equations of elasticity may be solved to satisfy these equations, noting, also, that there is no force system external to the body. If the vertical displacement is u and the horizontal displacement is v, the solution of the differential equations leads to the following values:

$$u = \frac{K}{E}\,w\,x\,y$$

$$v = \frac{1}{2}\,\frac{w}{E}\,(h^2 - y^2 - K\,x^2)$$

Before applying these expressions, it may be well to consider what the basic assumptions are and what limitations must be placed on the interpreta-

* "A Treatise on the Elastic Theory of Elasticity", 2d Edition, pp. 124-125.

tions of the results. The differential equations are derived fundamentally from the linear stress-strain law, that is, Hooke's law. The material must be isotropic, that is, it must possess uniform elastic properties in the directions of the principal axes, or it must have elastic properties symmetrical about the y-axis. A homogeneous rock mass may fulfill these conditions to some extent. A coherent soil may act as if it, likewise, possesses such elastic properties. It should be clear, however, that any geologic formation can only be treated sketchily as an elastic solid and the results based on elastic research can be most precursorily applied. Experimental observations seem to place more optimism on the application of the elastic theory and, surely, for mere qualitative studies the elastic theory will provide good working clues if nothing else. Thus, a mere sketch study of the stress systems will indicate weak planes of resistance and also any incipient motion of the mass, and it is in this sense, and probably in this sense only, that the analysis can be made to serve practical purposes. With this point in mind, the mathematical work may be continued.

The previously derived expressions for u and v determine the movement of the particles of the body under stress and, for the ordinary elastic solids, actual stresses may be derived from these displacement equations. These stress equations will not be derived for the material at hand. Plot two families of curves: (1) The curves formed by placing u equal to a series of constants; and (2) those formed by placing v equal to a series of constants. A system of ellipses will then indicate the points of the same downward motion and a system of equlilateral hyperbolas will indicate points of the same lateral movement. (See Fig. 6.) It is seen that the maximum lateral movement occurs at the bottom of a cut, giving a theoretical verification of the fact, noted in practice, that coherent earths, such as clays and soft rocks, tend to push out at the bottom. The ratio of u to v gives the direction at each point of the impending motion, and Fig. 7 illustrates such lines of actual particle paths. This, again, seems to confirm observations made of the action of materials in deep cuts* and indicates a possible mode of failure of retained banks or of braced banks, if the sheeting gives way. Geological formations appear to follow a law of the type indicated, as far as the formation of gorges, etc., is affected.

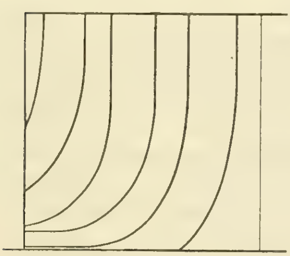


FIG. 7.

In Fig. 6 and Fig. 7, values corresponding to a concrete have been used in plotting the curves. Thus, w is taken at 150 lb. per cu. ft.; E at 1 500 000 lb. per sq. in.; and K as one-fifth.

One hesitates to draw any further conclusions from this mathematical work, except the qualitative ones just observed, although the partial concordance with experimental data may tempt one to carry the analysis a trifle farther. The motion of the mass under stress takes the character shown in Fig. 7 and in

* See the paper by Moulton previously mentioned ; see, also, "Mechanics of Panama Canal Slides", by George F. Becker, U. S. Geological Survey.

coherent soils one would expect that, as failure occurs, that is, as a slip starts, a mass would break away, with a bounding surface as shown by one of the curves in the diagram. Again, there is experimental confirmation of this indicated movement, as it is readily observed that when a coherent bank breaks, the break is roughly hyperbolic in form. The writer has analyzed this point on another assumption,* arriving at about the same conclusion, as far as the form of the surface of slip is affected. The extension of lateral earth-pressure analysis to include such breaking surfaces as a basis of the so-called granular theories may produce results that will bring the formulas in better accord with experimental data. In passing, it may be stated that the familiar theories of Coulomb, Rankine, etc., are predicated on plane surfaces of rupture.

One other method of obtaining a solution of the transmission of pressure through coherent soils and rocks remains to be discussed. It has been suggested that the solution of the problem of the movements of materials in deep cuts may be found by a study of the laws of plasticity and partial viscosity. This method has been used in observing the slides at the Panama Canal,† and the basic method is predicated on a plastic condition similar to a hydrostatic condition in which, under a high stress, the materials tend to flow. Dr. Becker has assumed that the weakest resistance to failure in a rock material is that to tangential shear. Under a high pressure, the unit tangential shear may be taken the same as the unit compression. Thus, if an arc of the surface of failure is analyzed, of length, $d\,s$, and of angular turn, $d\,\phi$, and if the depth is y, so that the unit compression is $w\,y$, as before, and T is the tangential shear that is to cause failure, the following infinitesimal relation holds true:

$$\frac{T}{w} = y\,\frac{d\,s}{d\,\phi}$$

It will be noted, by those interested, that this is the identical equation of the elastica, the type of curve that the slender column takes under an axial load, and the solution leads to the same form of equations.

As the radius of curvature is found from the relation, $R\,d\,\phi = d\,s$, the previously mentioned equation may be written, after placing $\frac{T}{w} = b^2$,

$$R\,y = b^2$$

If the radius of curvature is expressed in the usual form, as a function of the differential coefficients, the following differential equation is formed:

$$-\frac{\left[1 + \left(\frac{d\,x}{d\,y}\right)^2\right]^{\frac{3}{2}}}{\frac{d^2\,x}{d\,y^2}}\,y = b^2$$

Replace $\frac{d\,x}{d\,y}$ by p, and there is found,

$$-\frac{(1 + p^2)^{\frac{3}{2}}}{\frac{d\,p}{d\,y}}\,y = b^2$$

* *Engineering News-Record,* Vol. 86, p. 682.

† "Mechanics of Panama Canal Slides", by George F. Becker, U. S. Geological Survey.

noting that the second derivative is expressed in terms of p by the following relation,

$$\frac{d^2 x}{d y^2} = \frac{d p}{d y}$$

Separating the variables, the equation becomes,

$$\frac{y}{b^2} d y + \frac{d p}{(1 + p^2)^{\frac{3}{2}}} = 0$$

the substitution of tan u for p leads to a simple integration, and the equation becomes,

$$\frac{y^2}{2 b^2} + \frac{p}{\sqrt{(1+p^2)}} = c$$

If the constant is taken as equal to zero* (making the curve normal to the upper bounding surface), and the equation is then solved for p, or, for its equivalent, $\frac{d x}{d y}$, there is found,

$$\frac{d x}{d y} = -\frac{u^2}{\sqrt{(1 - u^4)}}$$

u is equal to $\sqrt{\left(\frac{y^2}{2 b^2}\right)}$. The constant, $2 b^2$, is a large quantity, as a study of the ratio, $\frac{T}{w}$, indicates and, therefore, u will generally be less than 1. A study of the differential equation shows that $\frac{d x}{d y}$ becomes infinite when $u = 1$, and the tangent to the curve becomes parallel to the x-axis. For large values of y, that is, for values where failure is impending, the curve is normal to the vertical, agreeing with the results shown previously. To solve the differential equation, place,

$$\sin \phi = \sqrt{(1 - u^2)}$$

This reduces the equation to the standard form of the elliptic integrals of the first and second kind, with the modulus, k, equal to $\sin^{-1}$ 45 degrees. The solution of the equation leads to the following form:

$$x\dagger = C' + \frac{F (\cos^{-1} u) - 2 E (\cos^{-1} u)}{\sqrt{2}}$$

F is the elliptic integral of the first kind and E is the elliptic integral of the second kind.‡

For different initial values of x, the curves of incipient failure are shifted laterally along the x-axis, so that the constant merely determines the starting point of the curve for $u = O$. Fig. 8 shows a family of these curves. When

* A study of the curves shown in Fig. 8, will indicate that other values assigned to the constant will merely change the initial direction of the curve a small amount.

† For simplicity, $b \sqrt{2}$ is taken as unity.

‡ Tables of their values may be found in Peirce's, "A Short Table of Integrals", and in Jahnkes' and Emdes' Handbook.

proper values have been found for the material coefficient, $\frac{T}{w}$, these curves may obtain quantitative worth, but as they are shown, they indicate the possible failure surfaces and bring the plastic or after-elastic effect into harmony with the elastic effects shown.

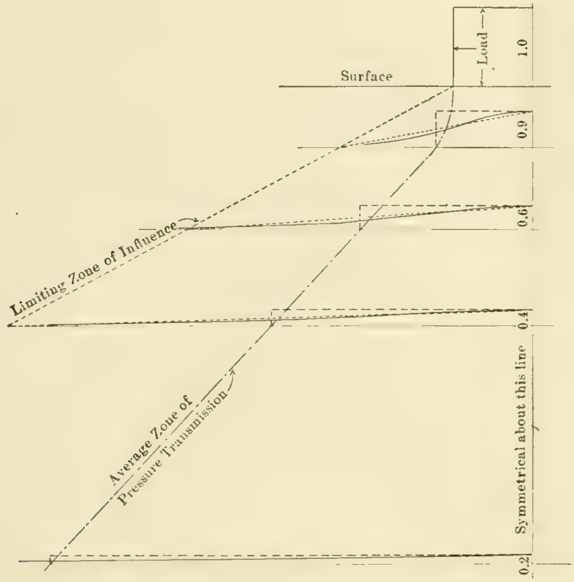


FIG. 8.

It is more than a coincidence that a study of the transmission of pressure by several elastic methods and by an "after-elastic" method leads to failure curves of like form, and the writer feels confident that, as a conclusion, it may be pointed out that the lines of transmitted pressure are substantially the same for all types of material and that the diagrams in this paper represent with qualitative, and, to some extent, quantitative, accuracy, the stress paths in monolithic masses subjected to their own or to imposed weights.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

FLOOD PROBLEMS*

A SYMPOSIUM

By Messrs. J. G. Sullivan, Gerard H. Matthes, Nathan C. Grover, John R. Freeman, J. A. Ockerson, Roy N. Towl, Arthur P. Davis, C. E. Grunsky, and Charles H. Paul.

With Discussion by Messrs. Morris Knowles, Harrison P. Eddy, J. Albert Holmes, D. W. Mead, Arthur O. Ridgway, J. B. Challies, George M. Lehman, W. H. Breithaupt, and Adolph F. Meyer.

* Presented at the meeting of the Society at Dayton, Ohio, on April 5th, 1922.

FLOOD CONDITIONS IN CANADA

By J. G. Sullivan,* M. Am. Soc. C. E.

About three years ago, the speaker became associated with the Manitoba Drainage Commission and, possibly, on account of this association, the Government of Manitoba has asked his advice on some real "flood problems". The two important points on which the Commission desires confirmation of its conclusions are:

First.—Does the clearing of timber from land and the cultivation of the land increase the run-off?

Second.—If the first question is answered in the affirmative, what responsibility, if any, attaches to the lands from which the extra water comes; in other words, what lands can be included in an Injuring Liability Clause of the statutes?

The Manitoba Drainage Commission has reported to the Provincial Government on this point, as follows:

"Our final recommendation in the matter of boundaries is the extension of the boundaries of any drainage district to include all lands whose surplus waters drain into said district and are carried by any artificial channel through it to a natural outlet. This is a natural division of lands, any other division leads to disputes.

"We do not contemplate that all lands within the new boundaries should be taxed. In the case of Drainage District Nos. 19 and 8, the lands west of these districts on the Riding Mountain are in a Government reservation and covered with timber, which latter fact, in any case, would relieve them of taxation for drainage cost."

In order to explain conditions and circumstances relative to a part of the valley of the Red River, south of Winnipeg, the speaker will quote further from the report of the Drainage Commission, as follows:

"In Drainage District No. 2, aside from the claim of inequitable taxation, complaints have come from three classes: First, from those living in the low lands which never had been drained, although the land has been taxed the same amount as all the other lands in the district. Second, from those who had at one time drains that became ineffective through lack of maintenance, and these people pointed with scorn to what they termed 'Government drains' which were full of soil which had blown into the ditches or had become so foul with uncleared brush, and other growths, that they could not properly function. It was surprising how few people realized that the municipalities and not the Government were the parties responsible for maintenance work. The complaint of those who never had protection is well founded, and they should be given relief as soon as it is possible to finance the necessary funds. The third class of landowners to complain are those suffering from flood waters, which waters spread over the low lands and destroy crops as occurred the first part of July in this year, or they occur in the spring and leave the land so wet that crops are not put in, or else put in so late that they are apt to suffer from rust or frost.

"Your Commission is of the opinion that the losses in Drainage District No. 2 for the past ten years from this flooding would be at least ten times as great as the cost of works necessary to protect them from such floods.

* Cons. Engr., Winnipeg, Man., Canada.

"As to the cause of this trouble, part of it is due to lack of maintenance of ditches, which work according to statutes should be attended to by the officers of the various municipalities, but the Government cannot lay all the blame on the municipalities for the reason that they had the benefit of the advice of experts who realized the result of not properly looking after the ditches, and they should have realized that the Act relative to maintenance work was not practicable, nor would its enforcement result in equitable distribution of cost, and the Government should have changed same, or failing this, should have made it their business to force the municipalities to keep the works in proper condition regardless of results. However, the greatest factor causing damage from floods is the changed conditions since the districts were first formed.

"When Drainage District No. 2 was first formed, comprising 441 017 acres, there was nearly as much land west of the district only partly cultivated and quite extensively covered with timber. In 1887, in seven townships, in Ranges 4 to 6, there were 4 177 acres of cultivated land; in these same townships in 1890, the cultivated land was 7 994 acres; in 1915 the cultivated land amounted to 82 000 acres; and now practically all the land between the foothills and Drainage District No. 2 is cleared of timber and under cultivation, about 600 000 acres. Nearly as much more land is on the higher ground in this watershed and at the time Drainage District No. 2 was formed, nearly all the latter area was covered with timber. Since that time approximately 75% of these high lands have been cleared and put under cultivation, and the lands between the foothills and Drainage District No. 2 have been artificially drained by ditches built with Government aid and by road ditches. All of the work mentioned results in hastening run-off and, therefore, increasing run-off, for anything that hastens the run-off increases the same by decreasing absorption and evaporation. The result is that this extra water comes rushing down on the lower lands in Drainage District No. 2 at a time when the main channels are full of snow and ice, with the result that large areas are flooded and millions of dollars lost annually by failure to get a crop in or by rust on account of the lateness of getting in the crop. No matter how well the original channels were designed and no matter how well they were maintained, they would not now be capable of properly taking care of the extra rush of waters that come from the higher grounds on account of the changed conditions, and your Commission believes that the lands from which this water comes should help to pay a portion of the cost of carrying these waters to the Red River. It thinks that the proportion should be small compared with what should be paid by land that without drainage would be useless."

In a hearing before a Legislative Committee on this subject, contradictory testimony was given by old-time farmers. The men from the higher lands testified that the run-off from cultivated lands was much less than that from wild or timbered lands and stated, further, that the floods were much greater 30 or 40 years ago than at the present time; whereas, the witnesses from the low lands testified to opposite conditions. The Commission and its engineers contended that, in general, the run-off from a cultivated field in the soil of this country is greater from a summer fallow field than from one of wild land, or from timbered land. Further, in the case of melting snow under a warm sun or warm rains when there is frost in the ground to a depth of 6 to 8 ft., the run-off from the bare fields is much faster and is, therefore, greater than from the wild lands covered with heavy grass or timber. In such cases, with the water coming down in a rush when the ditches are full of snow and ice, the danger from floods is an annual menace to the lower lands. This argument has been borne out by experience in this District during the past 15 or 20 years, the spring flooding becoming more excessive and occurring more

regularly as the timber has been cleared and the land placed under cultivation. It is recognized that there are exceptions to this general rule; one exception would be where the ground was covered with say, 2 ft. or more of snow, the temperature during the day, not more than 40°, and with frost at night. Should this condition prevail for 2 or 3 weeks, all the snow would disappear through evaporation, and with a high barometer the moisture might be precipitated outside the water-shed and the danger of a flood would be less than if the land had been covered with timber and the snow held back until continuous warm weather and warm rains should come. If the weather turns from cold to continuous high temperatures, with the ground covered with snow, then, as is stated in the report, the timber would hold back the snow until the high temperatures had melted the snow and ice in the ditches. As to the claim that timbered lands in this district increase the danger of excessive floods, it will have to be admitted that there are conditions under which this is true, as has been indicated.

As a railroad man, the speaker has had several years' experience on the North Pacific Coast and any winter that the snowfall appeared to be a little greater than usual, the operating officers began to worry about danger from spring floods. After long experience, the speaker came to the conclusion that there was enough snow in the mountains every year to cause disastrous floods if conditions were right, namely, a continuous warm spell of weather with or without rain. In early spring, this condition is almost impossible, therefore, the time to begin to worry is when there is a cold late spring. Such were the conditions in the Northwest in 1894. The weather remained cold until May 24th, when it suddenly turned warm and on June 9th the water in Kootenay Lake was 31 ft. above low-water mark. The water was 3 or 4 ft. deep in the Canadian Pacific Railroad Station at Nelson, B. C., Canada. On the Arrow Lakes, the water rose to about the same height.

This brings up the flood problem of Manitoba. Winnipeg which is situated in what was the bottom of a lake not so long ago, as geologists count time, should not have been located where it is. The Red River, draining this area, has not cut a sufficient channel to prevent dangerous floods. Another adverse feature is that this river flows north. The present problem is to determine what will be the effect on the city and the lands between the International Boundary and St. Andrew's Locks, in the valley of the Red River, of works of flood control (other than the construction of reservoirs by the people of Minnesota and the Dakotas). Where natural reservoirs are not available, the usual practice is to increase the carrying capacity of the river by enlarging, straightening, and diking. It is possible to decrease the Red River to one-half its present length. The distance from Emerson to Winnipeg, *via* rail, is 60 miles. The river survey shows a distance of 120 miles and the speaker's information is that the same ratio obtained south of the boundary. The speaker is advising the Government of Manitoba, that, in his opinion, the work being done within the Province, of draining land and preventing local flooding in the tributaries of the Red River by double diking, etc., combined with that which is being done and may be extended south of the boundary, in time will bring about a condition whereby the City of Winnipeg and other property between

the boundary and St. Andrew's Locks, will be in danger of damage from floods annually, and, further, it is the frequent damage that is to be feared. For instance, with land damaged by floods annually to the extent of $1 per acre, with money at 5%, one would be justified in spending nearly $20 per acre to prevent such damage; but, if the land is damaged to the extent of $10 per acre, by floods once in thirty years, one would not be justified in spending more than $3 per acre to prevent this damage.

To sum up what the speaker wants to know, is, does clearing land, building drains, and diking streams, tend to increase the frequency of floods and, if so, is one justified in assuming that there is a responsibility on account of "injuring liability" attached to the higher lands?

FLOODS ON SMALL STREAMS CAUSED BY RAINFALL OF THE CLOUDBURST TYPE

By Gerard H. Matthes,* M. Am. Soc. C. E.

The object of this paper is to focus attention on the subject of floods caused by localized rains of great intensity, often styled cloudbursts, which affect principally the smaller streams. As far as the speaker is aware no comprehensive study of such floods has appeared in print. The difficulties in the way of collecting reliable data on this subject are too well known to require special emphasis. These difficulties rather than the infrequency of cloudburst floods account for the paucity of available data and the incomplete state of knowledge concerning this not only common but most destructive type of run-off. The speaker believes that much valuable information hitherto unpublished is contained in the files of engineers throughout the United States, and that these data, if brought together, collated, and analyzed by a competent agency, would go far toward throwing much needed light on this subject.

Definitions.—The term, "small streams", is applied herein to any watercourse in which the maximum rates of flood flow are caused, not by prolonged and widespread heavy rains, as in the case of rivers, but by downpours of exceptional intensity, of short duration, and covering areas rarely exceeding 50 sq. miles. Unscientific as the term, "cloudburst", may be, it is a common designation for such rains and has been used freely by engineers. It has been adopted by the speaker for want of a better appellation. The term, "excessive precipitation", in use by the U. S. Weather Bureau, is not satisfactory for the purposes of this paper, in that it is too general in its definition, and not sufficiently expressive of the particular kind of excessive precipitation under consideration. The speaker has been inclined to the use of the term, "torrential rain", but has found the one word, "cloudburst", simpler for his purpose. In further defense of its use, it may be of interest to state that other languages besides the English, notably the German, have literal equivalents for this term. For the sake of brevity, the term, "cloudburst flood", has been used by the speaker to describe floods in small streams, caused by cloudbursts or by precipitation approximating that of cloudbursts. No limit is specified as to the size of drainage areas of small streams as defined herein, as the definition given, places an automatic limit which must vary with local physiographical and meteorological conditions.

Distribution and Physiography.—Cloudbursts appear to be of common occurrence throughout the entire United States south of the 42d Parallel, some localities being more subject to them than others. In northern latitudes, they are not so common, owing, evidently, to the longer winter seasons during which strong convection currents are rare and the atmosphere is not capable of holding large amounts of moisture.

Topography is one of the governing factors in cloudburst formation, but the relation appears to be little understood. There is a feeling among some Western engineers that cloudbursts are peculiar to the arid regions. This is

* U. S. Asst. Engr., Chattanooga, Tenn.

not borne out by the facts; it is true, however, that in regions of small annual precipitation, like the Western States, cloudbursts form an important part of the annual rainfall, and exert a marked influence on the erosion features of the country. Whether cloudbursts can sculpture the relief of a region so as to make it thereby more susceptible, in turn, to the formation of cloudbursts, is a matter well worthy of investigation. The steep walled arroyos and smaller canyons of the West, no doubt, owe their formation and maintenance largely to this form of run-off. The deeply dissected rims and side canyons of the Grand Canyon of the Colorado River, a region noted for cloudburst precipitation, strongly suggest an intimate relation between topography and cloudbursts there.

Plains and table-lands seem to have a bearing, presumably in promoting atmospheric movements which are important in bringing, to the scene, moisture from over a vast radius. The entire east front of the Rocky Mountains in Colorado, especially along the foot-hills, has long been known as a zone in which cloudbursts are of common annual occurrence. The spectacular storms which took place there in June, 1921, except for their unusual severity, present no novel features in that respect. At the higher elevations in these mountains, cloudbursts are comparatively rare.

It is claimed that certain localities, because of peculiar topographic conditions, are immune from cloudbursts. The City of Chattanooga, Tenn., situated in a wide valley surrounded by high hills, enjoys this reputation. Less than 50 miles to the south, in Georgia, cloudbursts annually inflict much damage.

Whether proximity to bodies of water, such as large rivers, lakes, or the ocean, promotes the occurrence of such storms, is questionable. The records of Erie, Pa., and Baltimore, Md., given subsequently, seem to suggest that the nearness of lake or ocean has a bearing on the frequency of cloudbursts. However, reference to the record of Cherry Creek, at Denver, Colo., would dispel any such idea.

The bearing which physiographic features have on this entire subject, is so important as to invite the most detailed study. It is evident that a knowledge of both frequency and maximum rates of rainfall, that is, the class of information needed by the Engineering Profession in designing structures on smaller streams, hinges on a proper understanding of topographical and meteorological conditions as affecting cloudburst occurence. If any study has been given to the former, it has not come to the speaker's notice.

Damage.—Unlike river floods, which occur principally in the winter and early spring and often are beneficial by enriching the soil with silt deposits, cloudburst floods occur nearly always during the crop-growing season, and, next to tornadoes, are the most destructive agency with which the farmer has to contend. Washouts of railroad and highway embankments, destruction of bridges, culverts, and buildings, and loss of life, are common forms of cloudburst damage, which amounts to millions of dollars annually in the United States. As in other floods, the invisible damage often is considerable. The detouring of trains over neighboring lines, which, in many cases, costs more than the physical damage suffered by a railroad; interruption and loss of busi-

ness of all kinds; and, finally, the cost of human life, are some of the items commonly omitted in estimating flood damage. Many cloudburst floods are unnoticed by the press and by Government or State Bureaus. In fact, it appears to be nobody's business to study cloudburst occurrences. The speaker believes that if the toll taken annually by these floods were better known, it would attract greater attention to the problem of providing against them, and he takes this opportunity to emphasize the importance of collecting reliable statistics on this subject. This should be made the duty of some competent State or Federal agency.

Effect on Parent Stream.—Little damage usually results along large rivers from the sudden emptying into them of one or even two tributaries carrying cloudburst floods, unless the main stream itself should happen to be at a high stage, in which case serious overflows may result. Ordinarily, however, small streams, overtaxed by cloudburst run-off, cause only minor rises in the larger streams to which they are tributary. Perhaps the most harmful effect in such cases is the deposition of a vast quantity of débris in the channel of the larger stream, at a time when its waters are not capable of transporting such débris. The speaker has seen such accumulations of débris spread out fan-shaped at the mouth of the offending tributary, resembling, on a small scale, the well known alluvial cones of the California mountain streams where they emerge from the Sierras. A noteworthy feature of such débris fans is their symmetry, indicating that the flow in an up-stream direction in the main river channel was, temporarily at least, nearly as strong as that moving down stream at the point of confluence. The speaker has been unable to ascertain the time required for a large stream to carry off such accumulations, but this, obviously, would depend on the frequency and size of its floods. This emphasizes the economic importance of floods in maintaining a proper balance in Nature's household. A river system, in many respects, is like an extensive sewer system—periodical flushings are essential to the proper maintenance of its channels. The removal of débris resulting from natural erosion agencies, such as cloudbursts, can be accomplished only through flood flow.

Rainfall.—No attempt will be made to discuss specific rates of cloudburst rainfall. Such data as have been obtained by the U. S. Signal Service, the Weather Bureau, and other sources, for the most part, are quite accessible in printed form. Such figures are of general interest only, and convey little that is of direct value to this discussion of the subject, lacking as they do, in the majority of cases, information regarding the distribution of the precipitation both as to time and areas covered. The spasmodic surging nature of cloudburst rainfall, accompanied by exceedingly localized concentration at a few points, renders ordinary rain-gauge observations of doubtful utility. Only self-registering instruments can be of use in such cases, and such instruments are so few in number as to furnish little information from which to draw conclusions. The recording mechanism of these instruments is not well adapted for clearly registering the tipping of the receiving bucket at each 0.01 in. of rain during cloudburst intensities. In one case, where 0.48 in. of rain fell in 8 min., the chart was so crowded that the ink lines had run together, and it was only by measurements of the water in the lower container that

the number of times the bucket had tipped could be ascertained. The chance of obtaining an accurate record of cloudburst rainfall by one rain gauge located within the area of heavy precipitation, belongs thus far in the category of fortuitous events. An instance where a fair record of this kind was obtained is the storm of July, 1914, near Cambridge, Ohio, when 7.09 in. of rain fell in 90 min.*

Field observations, made by the speaker, immediately following cloudbursts, have convinced him that such phenomena are often characterized by concentrated local falls of water lasting presumably only a few minutes and recurring probably at intervals at different points within the area of maximum rainfall. This is evidenced by surface indications in localities not subject to erosion by flow in natural watercourses or overflow from the latter. Thus, immediately after the cloudburst of July 10th, 1914, near Scranton, Pa., the speaker found scars high on a mountain side, that were from 3 to 5 yd. wide and nearly 10 yd. deep. Many cubic yards of earth had been torn as if by jet from an hydraulic giant. Similar scars, but of smaller dimensions, have been noted in Ute Pass, Colo., and at Dotsero, Colo., on other occasions. In these cases, there was no collecting area immediately above these scars, that could have produced sufficient concentration of flow on the ground surface to effect the removal of so much earth, and all the indications pointed to the action of water descending directly from the clouds.

Instances of cloudbursts within towns or cities corroborate this phase of cloudburst precipitation. A remarkable case of this kind occurred at Pittsburgh, Pa., on July 26th, 1874, at 6:30 P. M., when a cloudburst described as having formed by the coming together of two dark clouds, broke over the section of the city known as Allegheny. In a few minutes, more than 100 human beings had been swept down Madison Avenue into the Allegheny River, and 70 were reported to have drowned. About fifty houses were wrecked. In the same storm, cloudbursts occurred at Wood's Run, where 15 people were drowned, and at Sawmill Run, where 25 met death. These two small streams are in the immediate neighborhood of Pittsburgh. Nothing is known in regard to the rainfall during these occurrences.

The question may well be raised whether the study of cloudburst floods can be profitably undertaken through study of rainfall records as obtained by the present system of observation. Records showing that 6 or even 10 in. of rain fell within 1 hour are of small value when accompanied by the further statement that most of it fell in a part of that time. Statements of this kind are only too common. The average observer at a co-operative station cannot be relied on to make detailed observations at such times.

Run-Off.—Engineers are primarily concerned with the rates of maximum run-off and it is fortunate, therefore, that in cloudburst floods such rates are more readily ascertainable than the rates of precipitation which give rise to them. Even so, the information available is meager, and does not justify the drawing of definite conclusions at this time.

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* For a description of this storm and a map showing isohyetals, see page 16 of the "Ohio Water Problem", by C. E. Sherman, M. Am. Soc. C. E., in Ohio State University *Bulletin No. 10* (Vol. XX).

Being essentially of the nature of heavy thunder-storms, cloudbursts frequently occur during or in conjunction with them; they cover only small areas within the main storm, and have been known to recur again and again as the thunder-storm progresses. However, they are often isolated, and in such form they offer the best opportunity for detailed study. The storm at Long Level, Pa., described herein, was of this type. An outstanding feature of the isolated form is the comparatively small quantity of total run-off notwithstanding the extraordinary peak rates of flow. This is well brought out in descriptions of the floods of June, 1921, at Pueblo, Colo.,* and of September, 1921, at San Antonio, Tex.,† and afford the comforting thought that flood-control measures, especially by the retarding-basin method, may be economically possible in such cases.

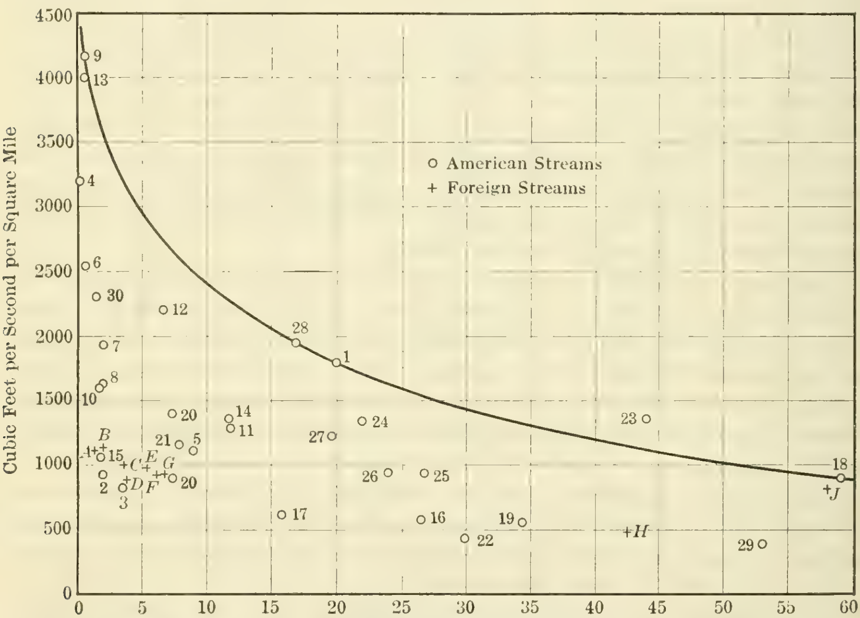


FIG. 1.

Fig. 1 shows a curve of cloudburst run-off compiled from data on American and foreign streams and Table 1 gives data pertaining to the cloudburst floods. The data derived from larger drainage areas are often complicated by the records of lesser rates of rainfall over parts of those areas, and as they do not offer so clean-cut a comparison have not been utilized. Furthermore, there is reason to believe that, for small drainage areas, high rates of run-off offer more nearly comparable results for different sections of the United States.

* "The Flood of June, 1921, in the Arkansas River at Pueblo, Colorado," by James Munn and J. L. Savage, Members, Am. Soc. C. E., *Proceedings*, Am. Soc. C. E., September, 1921, p. 167.

† "The Flood of September, 1921, at San Antonio, Texas", by C. Terrell Bartlett, M. Am. Soc. C. E., *Proceedings*, Am. Soc. C. E., November, 1921, p. 443.

TABLE 1—Cloudburst Flood Records.

	Stream.	Locality.	Date.	Drainage area, in square miles.	Peak run-off, in second-feet per square mile.	References.
	North American Streams:					
1	Willow Creek	Heppner, Ore	June 14, 1903	20	1800	*Water Supply Paper No. 96.*
2	Cherryvale Creek	Cherryvale, Kans.	....	2.0	930	*Transactions*, Am. Soc. C. E., Vol. LXXVII.
3	Estanzuela River	Monterey, Mexico	Aug. 25, 1909	3.5	825	*Engineering News*, Sept. 23, 1909.
4	Beacon Brook	Fishkill, N. Y.	July 14, 1897	0.25	3 200	New York State Engr.'s Rept., 1902.
5	Arroyo	Indiole, N. Mex.	July 19, 1915	8.87	1 105	*Bulletin*, Am. Ry. Eng. Assoc., August 1915.
6	Mann's Run	Creswell Station, Pa.	July 15, 1914	0.67	2 540	Water Supply Comm. of Pa.
7	Indian Run	Letort, Pa.	" " "	2.1	1 930	" " " " "
8	Canadochly Creek	East Prospect, Pa.	" " "	2.2	1 630	" " " " "
9	Bulls Run	Long Level, Pa.	" " "	0.58	4 170	" " " " "
10	Green Branch	Bridgeville, Pa.	" " "	1.7	1 595	" " " " "
11	East Fork, Honey Creek	New Carlisle, Pa.	July 29, 1918	11.8	1 285	Miami Conservancy District.
12	East Fork, Honey Creek	New Carlisle, Pa.	" " "	6.7	2 210	" " "
13	Dookers Hollow	North Braddock, Pa.	June 10, 1917	0.6	4 000	Water Supply Comm. of Pa.
14	Blue Ribbon Creek	Arkansas River drainage near Pueblo, Colo.	June 3, 1921	6.7	1 360	*Proceedings*, Am. Soc. C. E., Dec., 1921.
15	Arroyo		" " "	1.8	1 060	" " " "
16	Boggs Creek		" " "	26.5	582	" " " "
17	Arroyo		" " "	15.8	619	" " " "
18	Rock Creek		" " "	59	913	" " " "
19	Peck Creek		" " "	34.4	564	" " " "
20	Cameron Arroyo		" " "	7.3	1 900	" " " "
21	Osteen Arroyo		" " "	7.8	1 160	" " " "
22	Pinal Creek	Globe, Ariz.	Aug. 17, 1904	30	440	*Water Supply Paper No. 147.*
23	Elkhorn Creek	Keystone, W. Va.	June 22, 1901	44	1 363	*Engineering News*, Vol. 2, (1902) p. 104
24	Cane Creek	Bakersville, N. C.	May 20, 1901	22	1 341	" " " " "
25	Olmos Creek	San Antonio, Tex.	Sept. 9, 1921	26.8	930	*Proceedings*, Am. Soc. C. E., March 1922.
26	Apache Creek	" " "	" " "	24.0	947	" " " "
27	Martinez Creek	" " "	" " "	19.6	1 223	" " " "
28	Alazan Creek	" " "	" " "	16.9	1 950	" " Nov., 1921.
29	Santa Ysabel Creek	Mesa Grande, Calif.	Jan. 27, 1916	53	395	*Water Supply Paper No. 426.*
30	Mad Creek	Le Roy, N. Y.	June, 1916	1.5	2 300	*Engineering Record*, June 24, 1916
	Foreign Streams					
A	Wittgendorfbach	Germany	1887	1.3	1 115	*Transactions*, Am. Soc. C. E., Vol. LXXVII.
B	Dittelsdortwasser	"	1887	2.0	1 144	" " "
C	Wittgendorfbach	"	1887	3.6	1 010	" " "
D	Landwasser	"	1887	3.8	895	" " "
E	Kemlitz	"	....	5.4	980	" " "
F	Landwasser	"	1887	6.1	830	" " "
G	Spree	"	1887	6.7	930	" " "
H	Zacken	"	....	42.5	490	" " "
J	Pliessnitz	"	1890	58.0	820	" " "

Cloudburst at Long Level, Pa.—A description of this occurrence is given as being representative of the isolated type of cloudburst. It took place on July 15th, 1914, along the Susquehanna River, in York County, Pennsylvania, (Fig. 2), and covered an area of about 30 sq. miles. Field measurements were made on July 18th, 1914, by Howard T. Critchlow, Assoc. M. Am. Soc. C. E., assisted by Mr. W. A. Bowen, under the auspices of the Water Supply Commission of Pennsylvania, the speaker at that time being Division Engineer for the Commission, in charge of flood investigations. Through the courtesy of the Commission these data are here made available for publication. As the field work was done with painstaking care, at a time when traces of the floods

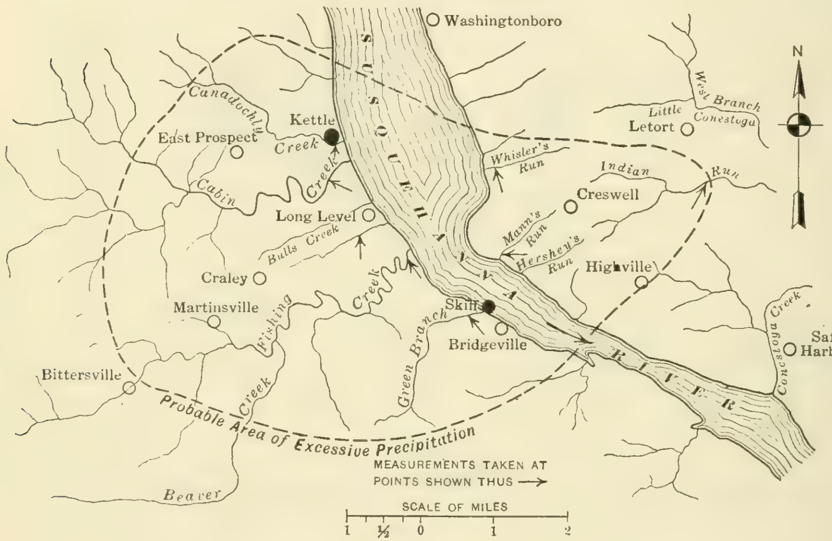


FIG. 2.

were still plainly visible, the speaker has considerable faith in the reliability of the results. The following is quoted from Mr. Critchlow's report:

"The storm broke between 3:30 and 4:00 P. M., of the 15th, and it rained very hard for about 2 hours on the area west of the river, while the precipitation lasted about 1 hour on the east side, beginning about 4:30 P. M. The inhabitants interviewed stated that the downpour was the heaviest they had ever seen, the clouds coming from several directions and hanging over them. There was only slight wind and electrical disturbance. Data obtained from a party near the mouth of Canadochly Creek, consisting of depth of catch in a large iron kettle standing in the open, gave a precipitation of 6.2 in. in 2 hours. Also, data obtained from a party at Bridgeville, consisting of catch in a 16-ft. skiff anchored on west shore of Susquehanna River, gave a precipitation of 5.7 in. in 1½ hours. These data check closely, and the former is especially good. Some hail was reported at Canadochly Creek and at Long Level."

* * * * * * * * * * *

"The data collected on this storm were obtained by W. A. Bowen and the writer as follows: East Side of Susquehanna River, Manns Run, Indian Run, and Whisler's Run on July 18th; West Side of Susquehanna River, Canadochly Creek, Cabin Creek, Cook's Creek, Bulls Run, Fishing Creek, and

Green Branch on July 21st and 22d. All elevations of high-water marks and low water, as well as cross-sections, were taken with small engineer's level, distances being measured with metallic tape. Courses were selected that were not subject to back-water, straight, and of fairly uniform cross-sections and slopes. These conditions were not always to be found, but it is believed that use was made of the best available. Measurements of span and clearance of culverts and bridges visited were made and recorded, but more time and attention was given to the collection of data on rainfall and for computing maximum rates of run-off. The duration of excessive rate of run-off is not definitely known. The small streams seemed to reach their crests within half an hour after the storm began, but the length of time during which flood conditions obtained and rate of fall is an indeterminate factor. They subsided rapidly after the storm ceased. Fishing Creek and Cabin Creek kept at crest for about an hour, the latter rising to crest from 4:00 to 6:00 P. M., remaining at crest until 7:00 P. M., and falling gradually to midnight. The rain here started at 3:00 P. M., and it rained hard for two hours. Any estimate of the total run-off would be subject to considerable error on account of lack of knowledge of rate of subsidence of flood. Only the maximum discharge has been computed, since it is the most important factor in considering flood conditions and the effect on bridges and dams."

TABLE 2.

	Stream.	Drainage area at section, in square miles.	Topography of basin.	Area of cross-section, in square feet.	Hydraulic radius, R, in feet.	Slope, S, ratio.	Value of n, Kutter's formula.	Maximum discharge, in cubic feet per second, per square mile.	Equivalent run-off, in inches per hour.	Remarks.
1	Manns Run....	0.67	Steep, rocky slopes.....	127	2.68	0.0355	0.040	2 540	3.94	100-ft. course, fair conditions.
2	Indian Run (tributary to Conestoga Creek)........	2.06	Rolling, agricultural land........	378	2.90	0.015	0.035	1 930	3.00	200-ft. course, good conditions.
3	Canadochly Creek........	3.24	Hilly agricultural land........	316	4.06	0.013	0.035	1 120	1.73	200-ft. course, good conditions.
4	Cabin Creek ..	13.9	Hilly agricultural land........	255	2.69	0.010	0.035	359	0.56	Computed at timber dam, 70-ft. crest, head = 5.0 ft., by $Q = 3.7\ L\ H^{3/2}$, and by open-channel method for area over right bank.
5	Bulls Run.....	0.58	Steep, rocky slopes.....	213	3.49	0.039	0.045	5 560	8.62	200-ft. course, poor conditions.
6	Fishing Creek.	18.2	Hilly agricultural lands......	216	3.85	0.013	0.035	172	0.27	Entire basin not covered by storm; main tributary, Beaver Creek, not flooded.
7	Green Branch.	1.66	Steep, rocky slopes......	126	3.82	0.055	0.040	1 595	2.48	75-ft. course, fair condition.

The results of Mr. Critchlow's measurements are given in Table 2, from which it will be seen that the conditions surrounding the determination made on Bulls Run were poor, the first inference being that the rate of run-off of 5 560 sec-ft. per sq. mile from 0.58 sq. mile is too high. The speaker has not discarded this measurement, however, as it was made in nearly the center of the area of heavy precipitation, and it seems reasonable to expect a higher

rate of rainfall as well as of run-off there than at other points in the area. He has arbitrarily discounted the discharge by 25 per cent. The resulting figure, 4 160 sec-ft. per sq. mile corresponds, at 100% run-off, to 6.5 in. of rainfall per hour, which is not unreasonable for the center of this storm, the rates indicated by the kettle being 3.1 in. and by the skiff 3.8 in. per hour. The measurement on Manns Run also gives a run-off rate in excess of the rainfall rate indicated by the catch at the skiff, the difference not being sufficient, however, to warrant rejection.

Frequency.—In the eastern half of the United States practically no gauges are used on small streams, owing to the small economic importance of their flow. Many gauges have been established within the past fifteen years in the arid regions, where it is no longer unusual to see an automatic register chart showing the complete oscillations caused by a cloudburst flood. However, the records so available are too short to be indicative of the frequency of recurrence. The best that can be done is to study the history of small streams traversing some of the older cities. The record of Erie, Pa., mentions a flood on September 13th, 1878, when Mill Creek swept away dams, culverts, bridges, and caused the loss of two lives.* The rainfall recorded at Erie was 5.11 in. on September 12th and 13th, 1878, but no data are available as to what fell within the area of excessive precipitation. Later well-known floods that caused havoc were those of May 17th, 1893, and August 3d, 1915, the latter finally arousing the citizens to the necessity of providing relief.

The cloudburst flood on Willow Creek, that destroyed Heppner, Ore., on the night of June 14th, 1903, seems to have had a precursor in 1883, before the town came into existence. In 1888, a flood fully as serious as that of 1903, came down Hinton Creek, which empties below Heppner.†

Jones Falls, a small stream which flows through Baltimore, Md., has perhaps the longest available record of cloudburst floods. The first flood recorded is that of July 30th, 1754, the details of which are meager. The flood of October 5th, 1786, occurred in the late evening and was very destructive to property of all kinds. Other similar floods occurred on August 8th, 1817; July 14th, 1837, noted for the many lives that were lost; August 24th, 1842; June 12th, 1858, said to have equalled in destructiveness that of 1786; May 11th, 1860; July 24th, 1868, which swept away stone and brick bridges across Jones Falls; and July 23d, 1887. Of recent years, the magnificent sewer system of Baltimore, in which Jones Falls is made to flow in a covered channel through the city proper, has prevented flood damage. In about 150 years 9 floods occurred at intervals averaging 17 years. This compares closely with the Erie record, in which the floods were separated by 15 and 22-year intervals.

Cherry Creek which flows through Denver, Colo., is a well-known offender. It has a drainage area of about 400 sq. miles, and belongs to that class of streams in which extreme flood stages may be caused by long protracted rains, or by rains of the cloudburst type. The report of the Cherry Creek Flood Commission shows that floods caused primarily by rainfall of the

* Report of Chief Signal Officer, 1879, p. 583.

† U. S. Geological Survey, *Water Supply Paper No. 96,* by E. C. Murphy.

cloudburst type occurred on May 19th, 1864, May 22d, 1878, July 26th, 1885, and July 14th, 1912, averaging 18 years apart.

Another long record is that of the old City of York, Pa., through which flows Codorus Creek, a stream draining an area of 223 sq. miles. Selecting the most disastrous floods on this creek, commencing with 1744, the record shows a total of twelve. Of these, that of March, 1784, was caused by overflow from an ice jam, and that of February 21st, 1822, was caused by heavy rains falling on 18 in. of snow. The remaining ten appear to have been caused by extraordinary rains. Excluding that of 1772, concerning which little appears to be known, the occurrences were, as follows: In the summer or fall of 1744 and, again, in 1758, both floods being described as having caused great damage to the crops of the pioneer settlers; October 5th, 1786, when storms of unusual intensity swept various parts of Pennsylvania and Maryland; August 8th, 1817, when $200 000 damage was done in York County, the rainfall being said to have totaled 8 in. in 13 hours; May 29th, 1821, said to have been less destructive than that of 1817; October 8th, 1847, caused by extraordinary torrential rains; July 19th, 1850, which exceeded in height any flood since 1822; and June 25th-26th, 1884, said to have exceeded that of 1817, and to have been caused by a rainfall of about 12 in. in 7 hours. This flood swept away all the bridges in York, then a prosperous city. It was shortly followed by the flood of July 5th, 1884, caused by cloudburst rains within the Codorus Creek basin, producing unprecedented stages in some of the smaller tributaries. These nine floods occurred at intervals averaging 18 years. The speaker submits this record because of its value in studying the frequency of recurrence of extraordinary floods in a stream draining an area of about 200 sq. miles. The extent to which the cloudburst run-off figured in these floods cannot be definitely ascertained. It can only be inferred from the descriptions now available that precipitation of the cloudburst type did accompany these storms.

The dates mentioned are useful in throwing light on the recurrence of cloudburst floods, but without specific information as to peak run-off rates they are of small value to the engineer. They indicate, however, that cloudburst floods are more common than is usually conceded. The speaker hopes that other members of the Society may be able to supply similar records for other localities.

Flood Control.—Small streams have not been taken seriously enough in the past, and the property that has been placed within the reach of their flood waters can be protected, as a rule, only at considerable expense. The successful curbing of unruly small streams by some communities is encouraging, and it is hoped will find following elsewhere. The municipalities of Harrisburg, Pa. and Watervliet, N. Y., were among the first to adopt the system of retarding-basin control, and it has been so successful that reports concerning these works are scarcely ever heard, a sure sign that they are working properly. In the Miami Valley, the catchment areas of the streams now under control were, for the most part, too large to be within the class of streams dealt with in this paper. Nevertheless, computations were made to make sure of their safety in case of excessive rates of precipitation in short periods of time.

The Germantown and Lockington Dams each control streams draining areas of a little more than 250 sq. miles. These are in the borderland of the class of streams herein discussed. Although primarily designed to take care of the run-off from storms like that of March, 1913, and greater, these dams are capable of controlling floods of the cloudburst type.

In some localities, because of local conditions, channel improvement and levees may be the only form of protection that can be provided. The retarding-basin system, however, offers special advantages for handling this class of floods, as the total flood run-off is not large and does not require basins of great size.

Design of Structures.—Protection of property against inundation is often a problem, in which the value of the property and other financial considerations limit the size of flood that shall be protected against. Waterway to pass maximum floods cannot always be provided under bridges, but bridges can be built to withstand the onslaught of great floods without failing. Culverts over small channels often have inadequate waterway when the conditions would make adequate waterway possible without unreasonable expenditures. Whether it is better to permit highways and railroad embankments to be washed out, at long intervals, rather than provide costly structures over small streams, is a matter of maintenance rather than of engineering, the damage to adjacent property being important in such considerations. Good engineering would seem to demand adequate structures, unless the road or railway is of temporary character.

In the design of spillways, it has been considered proper to build for the largest flood, and often an additional factor of safety may be introduced. As more data on cloudburst floods become available, the tendency is to build larger and larger spillways, and there are cases where economy demands that such requirements be set aside in order to keep within reasonable limits. Should the engineer's conscience be flexible, or should he insist on providing a structure that will be safe under the ultimate conditions that Nature may impose? Is it better to inform a client that a safe structure cannot be built at the chosen site except at inordinate cost, and that, therefore, the project should be abandoned? Ingenuity and common sense, the two main attributes of engineering skill, can, in most cases, find a way out of such dilemmas. To permit the client to assume the risk of building an inadequate structure is not good engineering, nor will it save the engineer's reputation in case failure occurs.

Special considerations should apply to the remodeling of existing structures, where frequently radical changes are impracticable of introduction. Again, structures the failure of which can in no way imperil life or property now or at any future time, require no special safety factors.

Psychology.—The impressions made by flood catastrophes, however vivid at the time, soon fade from memory. An occasional flood, like that at Johnstown, Pa., becomes historical through the medium of school books and literature. Other floods equally serious from the engineer's point of view have been forgotten by the public. The Heppner, Ore., and the Oil City disasters are seldom mentioned. Few people residing in San Antonio, Erie, Baltimore,

or Denver, have any appreciation of the frequency with which their cities are visited by cloudburst floods, and this is true of hundreds of other towns in the United States. The hydraulic engineer cannot afford to forget; it is his business to provide himself with records that will enable him to make sound recommendations for flood control. For the larger rivers of the United States he is in a fair position to do so, although the records for many rivers leave much to be desired. For the smaller streams, however, the absence of reliable data is appalling. Many years ago, the Pennsylvania Company adopted the policy of systematically elevating its tracks above the highest known flood marks. Within the State of Pennsylvania, it has succeeded in doing so except for a few branch lines of minor importance. Thus, in large measure, it has freed itself from overflow by the flood-ridden rivers of that State. Not so, however, as regards the small streams—these continue to exact their annual toll of washouts. This is true of other railroad systems. In 1883, a cloudburst took out a large embankment on the Delaware, Lackawanna and Western Railroad about 1 mile east of Moscow, Pa. Again, on June 10th, 1892, a fill nearly 50 ft. high was washed out on this railroad near Moscow, the culvert at that point being unable to carry the flow from a cloudburst discharged by a drainage area of less than 5 sq. miles. On July 10th, 1914, the same fill went out by the same process. The Railroad Company restored the fill to its former lines, but replaced the culvert with a 16-ft. semicircular arch. The question may well be asked: Should bridges of ample span have replaced the culverts, or was the rebuilding of the embankments the logical thing to do?

In closing, the speaker wishes to state that he has purposely refrained from introducing into this paper a large collection of compiled data. Rather, it has been his endeavor to present as much as possible the results of his personal observations, covering a period of twenty years and extending over a large part of the United States. It is his belief that the present chaotic state of knowledge of cloudburst floods is due simply to lack of data, and that much could be accomplished toward placing this subject in its proper light if some agency would take on itself the systematic collecting of information pertaining to cloudbursts. The relation between topography and cloudburst frequency is a phase of the problem that merits especially exhaustive study. It is not enough to know how great rates of run-off can occur. It should be possible to foretell whether any given locality is subject to such rates by reason of its surrounding topography. It would be just as poor engineering to provide a structure of maximum dimensions in a locality that is immune from cloudbursts, as to build an inadequate structure in a locality where cloudbursts are bound to occur often.

STANDING WAVES IN RIVERS

By Nathan C. Grover,* M. Am. Soc. C. E.

Standing waves in rivers are due to several distinct causes and are known by many different names. They differ greatly in appearance, reach maximum heights of 20 ft. or more, and may be fixed in position or may move either with or against the current. In some forms, they are common and attract no attention; in others, they are unusual, spectacular, and, under some conditions, destructive to property and even dangerous to life. The four conspicuous and generally recognized types of standing waves are the hydraulic jump, caused by a sudden checking of the velocity of swiftly moving water; the sand wave, caused by moving sand on the bed of a stream that is heavily burdened with silt; the tidal bore, caused by the flow of the tide into a river; and the standing flood wave, caused by a sudden influx of a large quantity of water into a river channel.

Hydraulic Jump.—The hydraulic jump which is due to a sudden checking of the velocity of rapidly moving water and a corresponding increase in cross-section, may result from a sharp decrease in slope or from an abrupt increase in resistance to flow caused by an obstruction or a series of obstructions in the channel. By "facing" the current producing the wave and having no linear motion, it differs radically in appearance from other forms of standing waves herein described. It will occur where swiftly moving water flowing over a dam strikes the more slowly moving water in the pool below, where the jet of water from an orifice that is partly or wholly submerged strikes the relatively still water into which it flows, and where there is an obstruction or an abrupt increase in frictional resistance to flow. Practically all roughness of the surface of flowing water, except that caused by wind or by a sharp drop in the channel, is a manifestation in some degree of the hydraulic jump, although not commonly so called.

This phenomenon below a spillway dam and other hydraulic structures has been described and analyzed mathematically by Karl R. Kennison,† M. Am. Soc. C. E., Julian Hinds,‡ and S. M. Woodward,§ M. Am. Soc. C. E. In these descriptions, two important features of the hydraulic jump have been emphasized—the danger of the destructive effects of the jump on hydraulic structures and the possibility of utilizing the jump for removing part of the kinetic energy of the moving water. The destructive effects have long been recognized, and allowance has been made for them in the design of canals and flumes and of the foundations of overflow dams. The possibility of using the jump for dissipating energy is apparently much less widely understood and may be of sufficient importance to warrant further experimental study.

* Chf. Hydr. Engr., U. S. Geological Survey, Washington, D. C.

† "The Hydraulic Jump in Open Channels at High Velocities", *Transactions*, Am. Soc. C. E., Vol. LXXX (1916), pp. 338–420.

‡ "The Hydraulic Jump and Critical Depths in the Design of Hydraulic Structures", *Engineering News-Record*, Vol. 85, 1920, pp. 1034–1040.

§ "Theory of the Hydraulic Jump and Backwater Curves", Miami Conservancy District Technical Reports, Pt. 3, 1917.

Sand Waves.—Sand waves occur at high stages of streams heavily loaded with silt and are caused by the movement of considerable waves of sediment on the stream bed. The observed wave is, however, a wave of water, its causal wave of sand being entirely submerged. The sand wave may be due to the same causes that produce the hydraulic jump, but its occurrence is so striking and its appearance is so different that it is treated as an independent phenomenon. It appears to be due to a sudden checking of the velocity of the swiftly moving water, but it is caused by an obstruction that is in motion and that vanishes and re-appears with the dissipation and formation of waves or dunes of sand on the bed of the river.

These phenomena have been described by Gilbert,* who has called the waves of sediment on the bed "rhythmic dunes" and has made a distinction between "dunes", which travel down stream, and "antidunes", which travel against the current. The motion of the antidunes is caused by the deposition of sediment on their up-stream slopes and simultaneous erosion from their down-stream slopes. The dunes cause only slight undulations of the water surface, but the antidunes which travel much faster than the dunes, may cause waves of considerable magnitude.

R. C. Pierce,† Assoc. M. Am. Soc. C. E., who observed many sand waves in the San Juan River in Southern Utah, has described them as resembling in appearance "the waves thrown up by a stern-wheel river steamboat." He observed sand waves at least 6 ft. high, but they were generally only about 3 ft. high, measured from trough to crest. The length of the wave from crest to crest in the deeper sections of the river was from 15 to 20 ft. He describes their appearance as follows:

"At one moment the stream is running smoothly for a distance of perhaps several hundred yards. Then suddenly a number of waves, usually from six to ten, appear. They reach their full size in a few seconds, flow for perhaps 2 or 3 min., then suddenly disappear. Often, for perhaps half a minute before disappearing, the crests of the waves go through a combing movement, accompanied by a roaring sound. On first appearance it seems that the wave forms occupy fixed positions, but by watching them closely it is seen that they move slowly up stream. In the narrow parts of the stream the waves may reach nearly the width of the river, but in the wider parts they occupy smaller proportional widths. Usually they are at right angles to the axis of the stream, but at some places, particularly in the wider parts of the river, they may suddenly assume a diagonal position, moving rather rapidly across the stream in the direction toward which the up-stream side of the wave has turned."

Tidal Bore.—The tidal bore seems to be peculiar to a region of large tidal fluctuation and is formed in a tidal estuary where there are marked restrictions of channel or in a large river of strong current that enters the ocean. The effect is a piling up of the advancing tide on the lower layers, which are retarded by the normal current of the river. Many of these bores are destructive and are serious obstacles to navigation and shipping. The name "Amazon" is said by some authorities to be derived from an Indian word

* "The Transportation of Débris by Running Water", U. S. Geological Survey, *Professional Paper 86*, 1914, pp. 11, 242–243.

† "The Measurement of Silt-Laden Streams", U. S. Geological Survey, *Water Supply Paper 400*, 1917, pp. 41–43.

meaning "boat destroyer", because of the dangerous tidal bore about 100 miles above the mouth of the river. This bore occurs in a stretch of the river where the channel is obstructed by islands and the depth is not more than 4 fathoms. It advances at a rate of 10 to 15 miles per hour with a breaking wall of water from 5 to 12 ft. high. On applying Merriman's formula,* $v = \sqrt{g\,d}$, to these rates it is found that a velocity of 10 miles per hour (15 ft. per sec.) corresponds to a depth of wave of 7 ft. and that 15 miles per hour (22.5 ft. per sec.) corresponds to a depth of wave of 16 ft.

The tidal bore in the Ganges is noted for its magnitude and destructiveness. On the Hugli Branch of that river, the bore advances 70 miles in 4 hours, or at the rate of 25 ft. per sec., indicating a height of wave of about 20 ft.

Standing Flood Wave.—The standing flood wave occurs in a shallow stream when a large quantity of water reaches the channel while the stage is low. It may be caused by the sudden release of water through the failure of a storage dam or by heavy local rainfall. The same quantity of water reaching the stream at a higher stage would cause an increase of stage and discharge, but might not make a standing wave.

The standing flood wave is caused by the lag of water on and near the bed of a stream, due to the greater resistance to flow on the bed than on the water itself, which is shown by the ordinary curve of velocities in a vertical section of a river. In this respect, it is closely analogous to breakers on a beach and more remotely to the tidal bore. As a result of the lag of water near the bed, the swiftly moving water in the upper part of the cross-section of flow is continually overtaking the more slowly moving water below. A standing flood wave will be caused only when the quantity of water originally in the stream is small in comparison with the quantity in the sudden flood. Therefore, it is, perhaps, seldom the direct result of rainfall in humid regions, but it is a characteristic feature of streams in arid and semi-arid regions where low-water flow is small and precipitation has the intensity of the so-called cloudburst.

The flood wave appears as a nearly vertical "wall of water" with much splashing and foaming in front, caused by the continual falling of the faster moving water near the top over the slower moving water near the bottom. The water which thus falls becomes a part of the bottom layer of water, and other water from above overtakes and falls over it. The quantity in the bottom layers must, of course, be constantly augmented from above as the flood wave progresses, because the top layers must supply not only the water for their own extension down stream, but a large part of the water needed for an equally rapid extension of the slower moving bottom layers.

If a sudden rush of water should occur in a frictionless channel, the lower layers, acting under hydraulic pressure, would move forward more rapidly than the upper layers. In such a theoretical channel, nothing resembling a standing wave could form, as the piling due to the continual overtaking of the lower layers by the upper ones would be replaced by a flattening due to the more rapid movement of the water near the bed. It appears, therefore,

* "Treatise on Hydraulics", 8th ed. (1908), p. 342.

that friction of water on the bed is essential to the occurrence of a standing flood wave.

Merriman* has shown the mathematical conditions controlling the production of the standing flood wave. He finds that it will occur when the velocity becomes equal to $\sqrt{g\,d}$, provided c in the Chezy formula, $v = c\sqrt{r\,s}$, is less than $\sqrt{\frac{g}{i}}$, in which d is the depth of water, i is the slope of the channel, and g is the acceleration of gravity. The condition of this proviso will prevail only if c decreases—that is, if the frictional resistance to flow increases—as the slope of the bed increases. In other words, the steeper the slope, the greater the frictional resistance essential to form a standing flood wave.

Although, in the aggregate, many more standing flood waves are formed by excessive precipitation than by the failure of reservoirs, rainfall does not generally produce the best conditions for such waves, because water derived from rainfall normally reaches the large drainage channels in part through many tributary channels that are more or less separated and in part as sheet flow over the surface of the ground, the result usually being a gradual increase of water in the stream bed rather than a sudden rush of water from one source. The natural increase down stream in channel capacity and the effective storage of water required to fill the channel and cover the flood-plains also tend to counteract the conditions that promote the formation of a standing wave. As a result, standing flood waves are formed from rain only when the local precipitation is unusually intense.

Unlike the tidal bore, which recurs periodically in the same stream, the standing flood wave cannot be anticipated and may recur in the same stream only at widely separated times. When it occurs, there are generally no facilities available for observing its velocity, its height, or its variation in velocity, height, or form, as it moves down a channel of varying width and slope. Consequently, few, if any, exact observations of the depth and velocity of standing flood waves have been made, and although such waves resulting from rainfall are frequently mentioned in general terms in both engineering and popular literature, there appear to be few published descriptions of their height and velocity.

Optimum conditions for standing flood waves occur in connection with the failure of reservoirs, of which the Lower Otay Reservoir, in California, afforded a typical example. The failure of that reservoir produced a standing flood wave that has been described as a huge wall of water from 6 to 20 ft. high, traversing the 10 miles from the dam site to Palm City in 48 min., corresponding to an average velocity of about 18 ft. per sec. This velocity corresponds to an average value of d (depth of wave) of about 10 ft. in the formula, $v = \sqrt{g\,d}$. Similarly, if the average velocity of wave of the Johnstown flood was 25 ft. per sec., as has been stated, the value of d found from this formula is 19.4 ft.

The four types of standing waves described pertain only to rivers and should not be confused with breakers, with the infrequent "tidal waves" of

* "Treatise on Hydraulics", 8th ed. (1908), p. 344.

the ocean caused by volcanic action or earthquakes, with unusual fluctuations of tides in bays or in estuaries into which no large river empties, or with those most common waves of all which are caused either directly or remotely by wind. These waves have been fully analyzed and described in engineering literature by several writers, and mathematical statements of certain of their characteristics have been presented to the Society by Karl R. Kennison, Assoc. M. Am. Soc. C. E., in the paper, to which reference has been made, and by Mr. R. D. Johnson.*

Obviously, however, the hydraulic jump and tidal bore form the basis of most discussions of standing waves in rivers, as they may be studied systematically at the will of the observer. In some respects the sand wave is interesting, but it is of little importance to engineers, because it occurs only in a few rivers that are heavily loaded with silt and that are, therefore, generally not utilized in hydraulic developments. The standing flood wave, as it occurs in natural channels, although seen many times and described in general terms, has not been and from its nature cannot be studied in detail, either as to causes, form, progress, or effects. These are good reasons why engineering literature contains no reliable information in regard to this spectacular and destructive phenomenon.

* "Surges in an Open Channel", *Transactions*, Am. Soc. C. E., Vol. LXXXI (1917), p. 112.

FLOOD PROBLEMS IN CHINA

By John R. Freeman,* President, Am. Soc. C. E.

The inclusion of notes on the flood problems of China in this Symposium might at first view not seem helpful toward the solution of certain flood problems of America, for which engineers are striving; nevertheless, there are certain important facts about training rivers to cut their beds deeper where they flow over deep alluvial deposits, recently discovered in course of the speaker's researches in China, that may prove of practical application in America and in other parts of the world.

Floods in China imperil the lives of a greater number of people than anywhere else on earth. Many of the great famines of China are caused by floods which, spreading to shallow depths over vast areas, even thousands of square miles, drown the domestic animals, destroy the growing crops, and make impassable the few poor roads, so that relief cannot be brought in. Many other of the great famines are caused by an occasional shortage of rain in districts where irrigation from controlled rivers or from storage reservoirs would insure food to lessen this starvation menace. In brief, there is no part of the world where the science and arts of hydraulic engineering could do more for humanity than in China.

The regulation and guiding of certain of China's great rivers in channels better adapted for flood control and for navigation present some of the most interesting problems of hydraulic engineering that can be found anywhere in the world, and the speaker has been led, through personal observation, to believe that the control of the rivers which cause these great floods is practicable to a large extent by modern engineering, and that it can be carried forward whenever China's domestic political affairs become straightened out and the inertia of extreme conservatism is overcome.

Until twenty or thirty years ago, the world outside of China knew little about these terrible floods, because means of communication within China were so poor that a knowledge of the facts filtered out slowly and imperfectly. For example, few now know that as recently as thirty-five years ago more than 1 000 000 people (some say 7 000 000) perished by drowning and starvation, resulting from one flood which came from a break through the south dike of the Yellow River, about 20 miles above Kai-feng City, and flowed southeasterly over a belt of nearly level country, perhaps 20 or 30 miles in width by 150 miles in length, into the Huai River. No accurate description of this outbreak or of its wide devastation appears to have reached Shanghai until after many weeks. Few to-day realize the awful devastation that followed the floods which, in August and September, 1917, surrounded Tientsin, the great commercial port of North China, submerged a large part of 15 000 sq. miles of delta plain, containing 105 cities and 17 000 of the little Chinese farm-villages, numbered 5 600 000 sufferers (by partial count of the magistrates), ruined crops estimated by the head of the Relief Commission to

* Consulting Hydraulic Engr., Providence, R. I.

have been worth \$22 000 000,* and caused a property loss several times this sum. Few who have not traveled in the Chinese deltas have any conception of the density of population or of the vast number of these little villages dotted everywhere over the fertile delta plain.

Floods that in any other populous country would receive world-wide attention occur two or three times in almost every decade at one part or another of the great eastern Chinese delta plain. In July, 1919, while the surveyors on the Grand Canal were in the field, there was a flood from an outbreak through the Yellow River dike, that ruined the crops over about 125 sq. miles

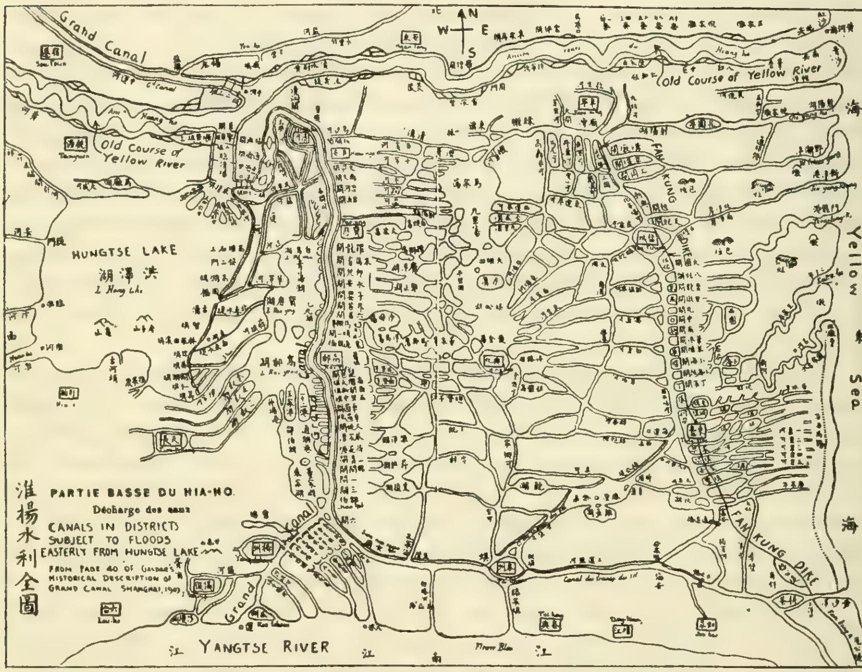


FIG. 3.—CHINESE PICTURE MAP OF KIANG-SU FLOOD.

of fertile land, supporting 560 villages and 217 000 people, and caused damages (as estimated by the local magistrates) to the extent of \$350 000; and in July, 1920, a hundred miles away from the area just mentioned, following sudden rain, there was an outbreak through the dike of a little river, that spoiled crops said to have a value of \$250 000, which outbreak was observed by the principal American field engineer. These two floods, of 1919 and 1920, were so commonplace in comparison with the great floods which always threaten, that so far as the speaker could learn, they escaped all notice in the several important English language newspapers published in China. The summer of 1921 brought a repetition, for perhaps the hundredth time in his-

* The distinction between U. S. gold and "Mex." silver dollars, an ordinary basis for estimating values in China, which are worth about one-half the gold dollar, has to be made plain in publications dealing with China. All values in this paper are calculated in U. S. gold dollars, at two silver for one gold.

tory, of great floods in Kiang-su Province and of another break in the Yellow River dike somewhere on the lower river, which is said to have caused great damage and a shifting of several miles in length of its channel, although no description of it has yet reached America.

In Kiang-su Province, along the branching outlets of the Huai River, north of the Yang-tze River and east of the Grand Canal, there is a flat delta plain of extremely fertile land extending nearly 100 miles north and south by about 50 miles east and west, which vast area, time after time, has been covered with water from the Huai floods, deep enough to drown most of the domestic animals, ruin the crops, and consign multitudes of people to starvation. An old Chinese picture map of this region in flood is shown in Fig. 3.* The area shown flooded covers about 4 500 sq. miles. This district which now supports an impoverished population said to number about 2 000 000, could be made, by means of construction works which the speaker believes practicable, to support, in comfort and safety, a population far greater than at present.†

The great industrial leader, Chang Chien, says, in his report of 1919, urging National action, "Within this district along the Huai River below the City of Wu-hu, in the past thirteen years, there have been six serious famines affecting thousands and thousands of people."

In the speaker's two brief tours of China, he has seen enough of some of these regions menaced by flood to convince him that no country has greater need of careful engineering research and sound cautious advice; and from his studies for the improvement of the Grand Canal and of the Yellow River, he is confident that great relief can be secured by an expenditure which relatively is not large and which can be forthwith recovered in the increased value of the land reclaimed. The construction can be performed mostly with hand implements, by native labor, which badly needs employment, at a smaller cost than by steam shovels, industrial railways, or dredges.

No part of the world gives greater opportunity for beneficent service to suffering millions of worthy, kindly, industrious people, by means of engineering skill, combined with a substantial construction-loan to the Chinese Government.

Concentration of the Floods

The outline map of China, Fig. 4, shows that run-offs from the principal river drainage basins are gathered into remarkably few main outlets to the sea, there being, within 2 500 miles of main coast line, measured without including the sinuosities, only five or six outlets to carry off the discharge from a catchment area about equal to the United States east of the Rocky Mountains. Naturally, the flood characteristics of these widely separated districts differ greatly.

* From Fr. Gandar's "Histoire du Canal Imperial."

† Ex-Minister Reinsch says in "An American Diplomat in China" (p. 60): "The people of the Huai Region, secure and affluent, might be easily increased by twenty million living heirs of a fifty-century old civilization.

Almost nothing was known of the detailed topography of the interior of China, until within the past 20 years, except from the journals written along single lines of travel by Abbé Huc, Pumpelly, and Richthofen; and precise information about the floods of these five great river systems is still limited to a few areas, large in themselves, but small compared with the whole of China.

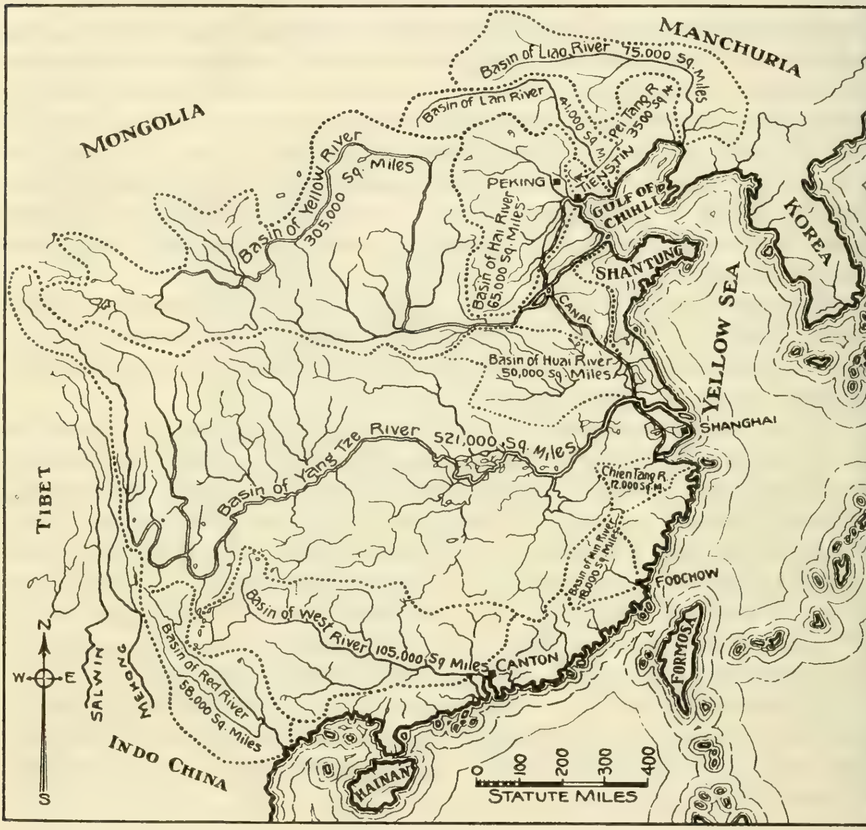


FIG. 4.—DRAINAGE MAP OF CHINA.

These particular flood areas about which something is known are mostly near the commercial centers. Doubtless these districts are the worst afflicted, because they are within the vast delta plains where a flood can spread. Back from these deltas near the sea, Chinese topography presents vast areas of hill and valley, which doubtless possess all ordinary varieties of the flood problems found in other parts of the world, that come from torrential rainfall and run-off in relatively narrow valleys, with great and rapid range from normal to flood height; for China has many rainfall records of 8, 12, and even 15 in. depth falling in a single storm, which equal and exceed that in the great storm of the Miami Valley.

This paper does not deal with those floods of upland regions. They concern fewer people and probably their control is to be found mainly in the slow processes of systematic forestry, or perhaps by barrages, such as are used in certain Swiss valleys, for preventing the landslides caused by torrents, from undercutting the steep hillsides.

Re-Forestation and River Training

The situation in general for flood relief requires much more than systematic forestry, although the sooner widespread re-foresting of the hills is vigorously undertaken, the better. The thickly settled lowlands of China are almost treeless, except small spots around the graves of ancestors, and during the past few centuries the uplands far back along the rivers have been robbed of their natural protection; it is certain that the cutting of the forests has had much to do with the present disastrous conditions. For example, up stream from Tientsin, vast areas of hills, from which floods descend, are said to have been stripped of their natural forest cover centuries ago and, consequently, their humus and their porous top soil have been largely washed away and the subsoil cut into gullies by torrential rains. Many of these steep slopes which, although unfit for growing grain, might be made to grow much needed timber, are now so bare that they shed water almost like a tiled roof.

Although forest litter, humus, and forest shade will unquestionably delay run-off from rain and snow in China as elsewhere, the disastrous delta floods on the Yellow and the Huai Rivers come largely from climatic and topographic conditions far beyond forest control. Forestry would protect the hill slopes and aid in moderating the lowland floods, but in the vast Chinese deltas, quicker positive safeguards are needed by means of channel control, new channels, and strong dikes, and these methods of relatively prompt relief seem feasible to the speaker whenever funds and proper direction can be had.

It seems probable that the new works of river training and dike building needed for the complete protection of certain large areas, which works, although extensive, are of a simple character, will cost annually far less than the present unreliable structures, and it also appears probable that the value of waste land that can be reclaimed by these new works could promptly be made to pay back to the Government, their entire cost and, in addition, bring prosperity to a vast impoverished region, and to other regions bring safety from impending disaster. All this complete flood protection, however, is no short and simple task, nor can the works be properly designed until scientific tests and painstaking observations have been made.

The speaker will present, in this paper, various tentative plans for flood relief in certain localities. Although these plans are the result of much study, and observation, he desires it clearly understood that, in their present form, they are suggestive rather than conclusive, and are subject to revision after more complete surveys. They are presented now in the hope of stimulating further investigation in the immediate future.

Some Localities Having Important Flood Problems

From north to south there are five principal localities within these main Chinese drainage basins, shown on the map, Fig. 4, in which flood relief needs to be intensively studied and great works constructed whenever the Government becames stabilized and capital gains confidence so that means can be provided. These localities are, as follows:

(1).—In the flat, level plains of the drainage basin that has its outlet past the great commercial city of Tientsin. This region suffered terribly in August and September, 1917. An area of about 12 000 sq. miles was submerged, and more than 1 000 000 people, mostly farmers, are said to have been driven from their homes. A property loss of more than $50 000 000 is said to have been incurred in this one flood with consequential damage of perhaps $100 000 000.

(2).—In the delta of the Yellow River, or Hoang Ho, along the river's 400-mile course through the delta. During the historic period of 4 200 years, this region has been ravaged time and again by floods in one place and another. These overflows come from breaks in the great dikes and occasionally cause a wide change in the river's source. So terrible have been these visitations that this river is often called "China's Sorrow". The conditions are aggravated by the silt burden, brought from the vast and easily eroded loess deposits of the Provinces just up stream from the delta, which make the Yellow River probably the muddiest great river in the world.

(3).—The Huai River District in Kiang-su Province below Wu-hu. About 5 000 sq. miles of this peculiarly low and level delta region is said to be frequently inundated, with famine often following flood. The land is exceptionally fertile and normally gives two crops per year, so that, for thousands of years, intensive cultivation has been continued in spite of disasters which, sometimes, have brought death to thousands and, at other times, have merely destroyed the second of the two yearly crops.

(4).—Along the Yang-tze River below Ichang. Here, in the Grand Gorges, the river floods are said to rise 80 ft., and below Hankow the flood discharge rises to about 3 000 000 sec-ft., which is about the same as the greatest flood discharge of the Mississippi River at New Orleans, La. The Yang-tze River, although turbid, brings down less silt than the Yellow River. Its delta, therefore, grows more slowly. Its whole regimen has become well established, and the flood problems are mainly those of ordinary dikes combined with river training on a mighty and forbidding scale, because of the depth and volume of water. The charts show dozens of spots where the swirl of the flood cuts pools more than 100 ft. deep, and it is no light problem to work out shore protection that will hold so deep a bank of soft fine-grained river silt when attacked by the undercutting of such a flood.

(5).—In Southwestern China the valleys of the North, East, and West Rivers, in the country around and back from Canton. Near the important City of Wu-chow, the great West River is said to rise 50 and even 80 ft. in extreme floods, and at the rate of 1 ft. per hour.

(6).—The improvement of navigation also presents incidental problems of flood scour, in addition to those of protection from inundation. There

are particularly great and difficult problems of river training for improving navigation, and problems of utilization of flood flow for scour of channels for harbor improvements, to be found on the Yang-tze near Shanghai, on the Min River near Foo-chow, and all along each of these five or six great silt-bearing rivers of China proper. The great depth of the silt deposit gives unlimited scope for the river to scour its bed deeper when confined in a generally straight and narrow way.

(7).—Outside the limits of China proper, to the northeast in Manchuria, there are great flood problems along the Liao River which rises in the Mongolian slopes and brings down silt that forms a harbor bar at New Chwang. On the other side, 17 000 miles away, in a straight line to the southeast, in French Indo-China, the lower course of the Red River presents serious flood problems which the French Government is said to be considering.

Besides the large problems cited, there are many smaller ones in drainage basins from 20 by 100 miles to 40 by 100 miles in extent, that are almost too small to show on the map of all China, to which floods may come once in 10, 20, or 40 years, that are terrible enough to the many people living on little farms or in little villages in their path. Examples of them were found in course of the Grand Canal surveys along the Wen River and in the Red Cross reconnaissance on the Yi River. Doubtless there are a hundred of these minor areas in fertile and densely populated parts of China, each of which has its own important flood problem which can be solved so as to bring a greater measure of security and happiness, whenever the Government becomes stabilized, a broader community spirit developed, and when the multitude of young Chinese, now studying modern engineering methods at home and abroad, are given the means wherewith to work.

Ancient Chinese Flood Protection

The Chinese have had to contend with the problems of flood control by dikes during their whole historic period of about 4 000 years and have developed some wonderfully good technique in many matters of dike building and in the repair of dike breaks. Although in the science of river training, they (and all engineers) still have much to learn, they have, in many great works, shown skill as hydraulic engineers. They have had some of the most difficult problems in the world with which to contend.

One of their most venerated men, of the half-legendary days of 3 000 years ago, was Yu, their great hydraulic engineer, to whose memory many temples were built and who, after a period of trouble, was entrusted with the conservancy of rivers throughout the country. He regulated the waters so wisely, it is said, that with his precepts faithfully followed there was no serious trouble for more than 1 000 years until "the period of the warring States". Tradition says, "Yu labored thirteen years, sparing neither trouble nor fatigue, nor even once entering his own home, though he passed three times before its door." That "he had boats for travel by water, chariots for travel by land, sledges for mud, with relays of men to draw them." "He dug nine great channels to conduct the waters to the sea," and he is supposed

to have organized the building of great systems of dikes. In the great fertile Province of Szechwan, many travelers have described great irrigation works and flood channels planned 2 000 years ago by an engineer, whose rules are said to be still implicitly followed. Tributary to the Grand Canal, at Tai-tsun-pa, there is a feeder dam, which the speaker has examined, of masonry resting on small piles driven into a soft sand foundation, that was admirably built about 500 years ago. The sea wall, of coursed cut stone, 25 ft. high, that protects the coast for many miles easterly from Hangchow, is a structure built about 400 years or more ago, of which any modern engineer might be proud. The fact that, during 538 years, the great restless Yellow River was held to its course on a silted bed several feet above the level of the ground on either side, within dikes built of soft friable river silt, carefully consolidated by tamping and protected from the erosion of impinging currents in many places only by groynes and revetments of earth bound together with perishable millet stalks, speaks volumes for the skill and resources of these Chinese "Old Masters."

Preliminary Surveys in Progress

In all the localities previously mentioned, investigation is now being carried on under the Chinese Government; but everywhere this work seems to be mostly in the surveying rather than in the engineering stage. It is far easier to make a tolerable survey than to make a good design and then establish confidence in it; and one gets an impression that the authorities having certain of these matters in charge are staggered by the size, complexity, and uncertainty of their problems, or are floundering in a "Slough of Despond", or may be forced, by pressure of the public demand for "making the dirt fly", into constructions that will not stand the test of time, and of which they themselves may have doubts. The data collected in these surveys and investigations are few in comparison with the vast territories in China affected by flood.

For investigations within the Hai River Drainage Basin, following the great Tientsin flood of September, 1917, the Chinese Government organized the Chihli River Improvement Commission which, under the guidance of English, American, and Chinese engineers, including three members of this Society, has, for about four years, been making topographic and hydrographic surveys, from which data, works may be planned later.

All along the Grand Canal in Shantung Province, the China Grand Canal Improvement Board, under the supervision of American engineers, members of the Society, has made extensive topographic and hydrographic surveys, and a reconnaissance survey of the Yellow River's course and its dikes for 200 miles up stream from the Grand Canal crossing. Plans have been devised for the immediate reconstruction of 253 miles of the Grand Canal, whenever this work can be financed; but from lack of funds, owing to the difficulty of selling Chinese bonds under present disturbed political conditions, the enterprise is now marking time.

Along two or three portions of the 400 miles of the Lower Yellow River within the delta plain, the Provincial Conservancy Boards are making out-

line surveys of the river's course and of its dikes, but with little attention to accurate hydrography or levels. Meanwhile, the Chihli River Commission is gauging the Yellow River flow and measuring, at frequent intervals, the percentage of silt that it carries, at the Tientsin-Pukow Railroad Bridge. The daily height of the Yellow River is recorded also at the Peking-Hankow Bridge, 302 miles up stream.

In Kiang-su Province, under the leadership of one of the most remarkable men in China, His Excellency, Chang Chien—classical scholar, Confucian philosopher, captain of industry, and philanthropist, full of the spirit of service to his fellow men—who seeks means for protecting his Province from floods, much of the delta land is being covered by a topographic survey made wholly by Chinese surveyors, that has been in progress for ten years, with ½-m. contours over large critical areas. This is accompanied by occasional, more or less accurate, river-flow gaugings.

For several years, the Harbor Board of Shanghai, controlled chiefly by the English, American, and French commercial interests, with a view chiefly to the improvement of navigation, has been making an excellent systematic and thorough survey of the neighboring Yang-tze River and its small tributary river, the Whang-poo, on which Shanghai is situated.

At Foo-Chow, some good river-training work is said to be in progress, mainly for improving the entrance from the sea to the harbor.

In Southwestern China, along the great West River and other rivers near Canton, some excellent preliminary hydrographic studies relative both to navigation and flood problems have been in progress for five years, in charge of Capt. Olivecroner, a Swedish engineer.

As a whole, the outlook for important construction, everywhere, is poor, because of internal political conditions, the impossibility of the present Government securing adequate funds, either by internal taxes or outside loans, and by the lack of community spirit, but the speaker believes that sooner or later China will find a way to work out its own salvation, and that the present outlook on stagnation will suddenly change.

Although China proper presents a range of latitude and longitude about equal to that of the United States east of the Rocky Mountains, this paper will be confined to the first three problems previously mentioned, which are found in the northeastern delta plain of China, north of the Yang-tze River, within an area, which, on a map of the United States, would about cover a triangle with corners at Buffalo, N. Y., Boston, Mass., and Washington, D. C. First the flood problems of the Yellow River, "China's Sorrow", will be briefly discussed.

Flood Problems of the Yellow River Delta

By far the largest of the Chinese deltas is that of the Yellow River which, with a radius of about 400 miles and an apex angle of about 90°, from its mountain exit, slopes seaward with wonderful uniformity at the rate of 10 in. per mile measured on a straight line, or about 8 in. per mile as measured along the river's winding course. Through millions of years this delta cone has been built up by deposits of fine-grained silt, brought down by the floods

from the vast loess deposits of Shansi and other Provinces. The flatness of the surface of this vast delta-cone is the cause of the great width and wide range to which a flood may spread when it escapes from the river's dikes. This flat slope may be due to the extreme fineness of the particles of silt,

FIG. 5.

which are mostly derived from the erosion of vast beds of loess, supposed to be accumulations of wind-blown dust, that originally came largely from the vast Gobi Desert. A moderate current can carry this fine-grained material a long way.

The Yellow River is not large in volume, compared with other great rivers of the world, although it is about 2 350 miles long, without counting the minor bends, and drains about 305 000 sq. miles. Within the historic period of about 4 200 years, the Yellow River has meandered and shifted from north to south, and back again, through this delta plain, occupying the nine widely divergent channels shown in Fig. 5.

The courses followed in these migrations appear to have first been brought to the attention of the outside world by the American explorer and geologist, Raphael Pumpelly, about 1865, in a series of small maps. The speaker had the map, which is presented on a reduced scale in Fig. 5, prepared in China, in 1919, by tracing on a sheet about 4 ft. square, the several courses laid down on a series of Chinese maps brought to his attention by the engineers of the Chihli River Improvement Commission. These maps were the work of a Chinese historian of about 100 years ago, who based them on the investigation of a Chinese author of about 200 years ago.* The Chinese have had some remarkably painstaking scholars and historians.

When a complete topographic map of China on a large scale is prepared, many additional details will probably be secured, because when one travels across the delta, many depressions, sand dunes, abandoned dikes, and other indications of ancient channels are found. Many town and provincial records have been kept for centuries, which note changes and floods with evident care. It is important that all these sources of data be searched and that a complete contour map be made of all the delta, showing all ridges and drainage channels, as a basis for many possible improvements; but the solving of the main problem of flood protection need not wait for this.

Since time immemorial, the river floods have been confined between dikes built of river silt, well-tamped into place, which dikes are guarded from erosion, wherever the river threatens, by spur-dikes or groynes commonly built with a facing of loose stone rip-rap over a core of earth and millet stalks, but sometimes built only of bundles of millet stalks, tied together with straw ropes, packed with earth, and pinned down with small stakes. This turning away of an impinging flood by spur-dikes is made easier by the great width of open ground between the dikes, which area is largely made unavailable for agriculture by the danger of flooding. On some of the higher silt banks of the flood-plain between the dikes, the farmer often sows his seed and takes a chance of loss of harvest if the annual flood arrives early.

Excessive Width Between Dikes

In general, along the upper 200 miles within the delta, and as shown in Fig. 6, these inner dikes are from 4 to 8 miles apart, although the necessary channel width at ordinary stages is only about ¼ mile, and for floods, less than ½ mile. The water sometimes spreads in a thin sheet over the elevated terrace of silt deposited between the normal shore line and the dike, to a much greater width than ½ mile, sometimes to the entire width between the inner dikes; but there are localities, as at Wei-chia-shan and Chang-kou, where the river happens to be confined between rocky hills projecting through the deep

* "Notes on the Tribute of Yu", by Hu Wei, published in 1708.

silt deposits, and here it flows in apparent comfort in a channel having a flood width of only about ⅓ mile, without abnormal fall, over a bed easily erodible to any necessary depth. Careful study of soundings and velocity measurements made of these localities proves that ⅓ mile is ample width of channel for carrying the greatest flood, and indicates that one-third of the length of the magnificent, German-built bridge at the Tientsin-Pukow Railroad, at Lo-kou, would have sufficed, with great saving of cost if accompanied by some adequate simple river-training works.

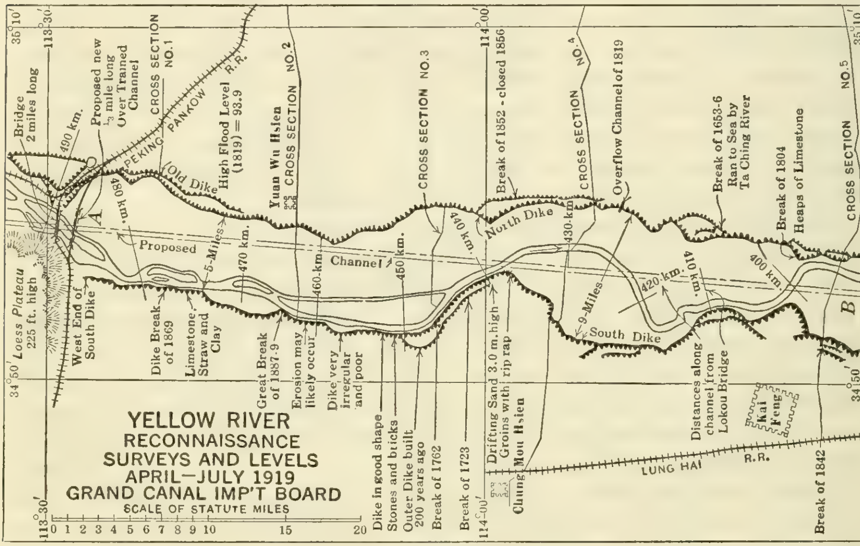


FIG. 6.

This great excess of width between dikes beyond that necessary for the flood channel or, for example, 5 miles instead of ⅓ mile, gives space for an ever-changing meander between these widely separated dikes, and when the bank is threatened by erosion this space permits the river to be deflected away from the dike on a long new course by means of new spur-dikes. This method of obtaining safety, while convenient, is extremely wasteful of land. The speaker believes that a great saving of land is possible and that, by methods to be described later, the safety against the outbreak of a flood can be greatly increased.

In 1919, the Grand Canal Improvement Board, in the course of investigations supervised by the speaker, surveyed and ran levels for several hundred miles along the Yellow River dikes and leveled on cross-sections across the channel between the dikes, and extended these levels several miles across the plain outside the dikes, so that positive information at many places is now available as to the relative elevations of river surface and of the ground outside, and, also, the slope of the river in flood and in drought, is known.

In December, 1919, the speaker cruised in a small boat, many miles down the river from near the apex of the delta, studying the dikes, currents, channel, sand-bar formations, and sites of some of the most famous dike

breaks, particularly those of 1869, 1887, and 1851. There seems to be hardly a 5-mile stretch of dike that has not been breached within the last few centuries, if the loops and groynes may be taken as evidence.

This excessive width between dikes prevails mostly within the up-stream 215 miles of the river's course within the delta. In the new course down near

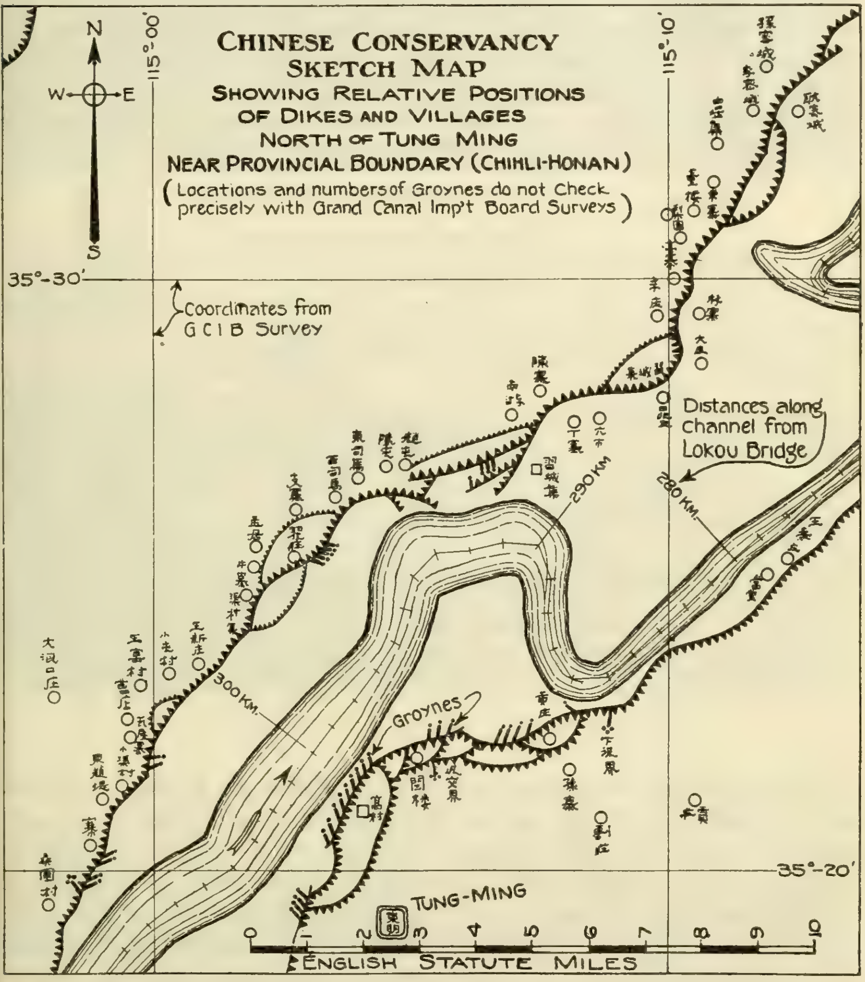


FIG. 7.

the old and new Grand Canal crossing, the inner dikes are little more than 1 mile apart for a distance of 20 miles along the river, but, here, the bed is not elevated above the plain outside the dikes. Seventy miles farther down stream, below the Tientsin-Pukow Railroad Bridge, the inner dikes average only about $1\frac{1}{4}$ miles apart for the first 20 miles below the bridge and about 2 miles apart for the next 50 miles, according to the map in Capt. Tyler's report of 1905.

An example of the relations of channel, main dike, loop-dike, and spur-dike, is shown in Fig. 7, which was traced from a Chinese conservancy map of the part of the river near the boundary between Chihli and Shantung Provinces, and begins about 60 miles down stream from the end of the section shown in Fig. 8. It is reproduced because it is typical of many miles of dikes. The sites of threatened or actual breaks, more or less ancient, are shown by loops of adjacent dikes built either as a part of the scheme of regaining control or as a precaution at a threatened break. Records of attempts of the river to undermine and cut through the dike are shown by the succession of stone groynes or spur-dikes, which were constructed, more or less hastily, to deflect the river from the threatened dike.

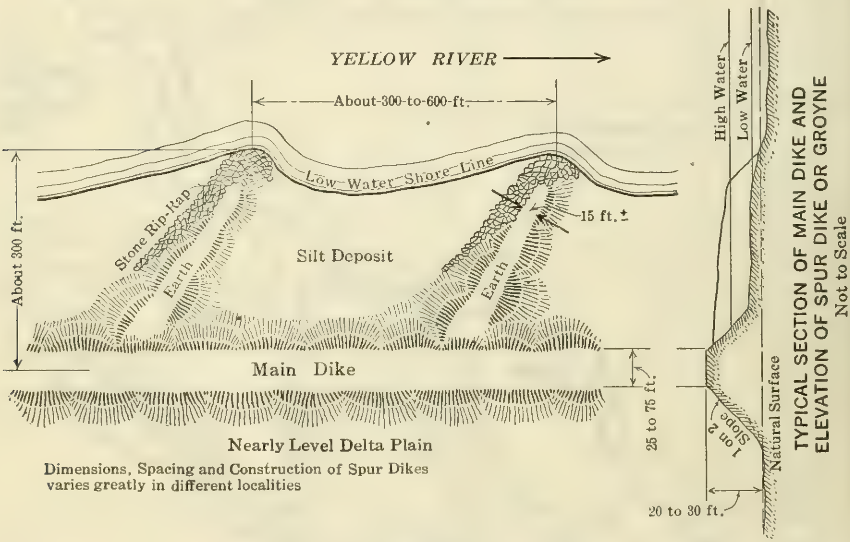


FIG. 8.

The general form and dimensions of these Yellow River dikes are shown in the photographs, Figs. 9 and 10. Fig. 9 shows the outer side of the main south dike at the site of the break of 1887, described subsequently. Fig. 10 is a view of a series of spur-dikes, looking up stream. Fig. 11 is a view of a dike gullied by rain, showing the friable nature of the earth.

Plate XX and Fig. 12 show several cross-sections surveyed in 1919 approximately at right angles to the river's course, in order to find the relative elevation of the river and that of the broad plain outside the dikes, and serve to explain the tendency of the Yellow River to break out, cause terrible floods, and change its course across the river bed. These sections give the first published accurate instrumental levels of wide range across the dikes and the outside plain of the Yellow River. The gross exaggeration of this scale, 1 000 vertical to 1 horizontal, should be kept in mind while examining these cross-sections. This magnification of vertical scale was required to make plain the differences of elevation in a country so extremely flat that to the

FIG. 9.—OUTER SIDE OF MAIN SOUTH DIKE AT SITE OF BREAK OF 1887.

FIG. 10.—SERIES OF SPUR-DIKES, LOOKING UP STREAM.

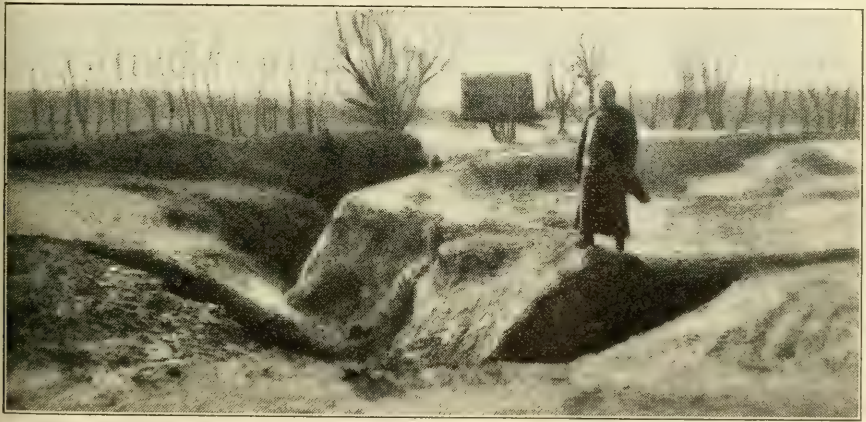


FIG. 11.—VIEW OF DIKE GULLIED BY RAIN.

eye it appears a vast level plain. Plate XX shows a greater width of the plain than Fig. 12 which is on a larger scale and shows sections above and below the break and change of course in 1851.

Some of those cross-sections of special interest are that at San Yi Chai, Fig. 12, taken 5 miles above the great break, which shows plainly the super-

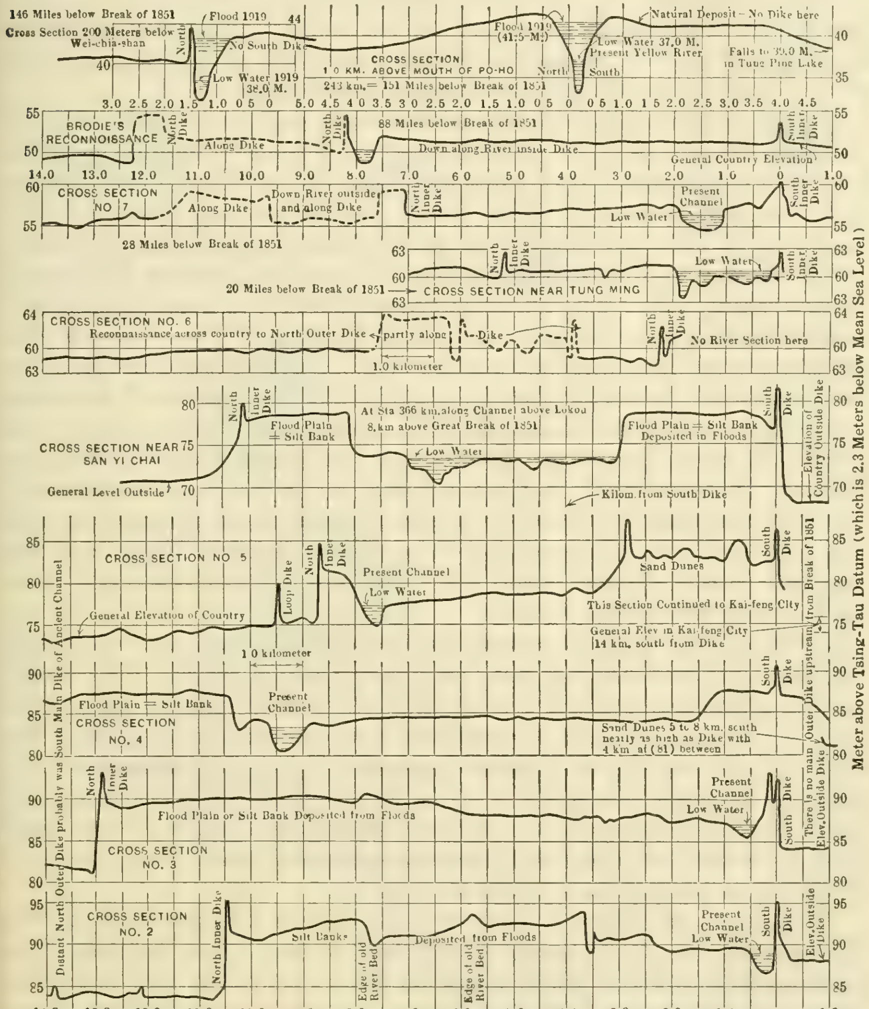


FIG. 12.

elevation of the river bed above the plain, and those at, respectively, 8 miles, 28 miles, and 88 miles, down stream from the break, which show no elevation of the river bed above the plain.

There has been much controversy among American engineers, interested in the Mississippi levees, about the super-elevation of the bed of the Yellow

River above the outside plain, and some good men of high authority have denied its existence. The proof is now available. The facts are that for 50 miles or more in length, above the outbreak of 1851 and along the old course below this outbreak, the river bed is slightly above the plain, whereas, along the new course, it is slightly below the plain.

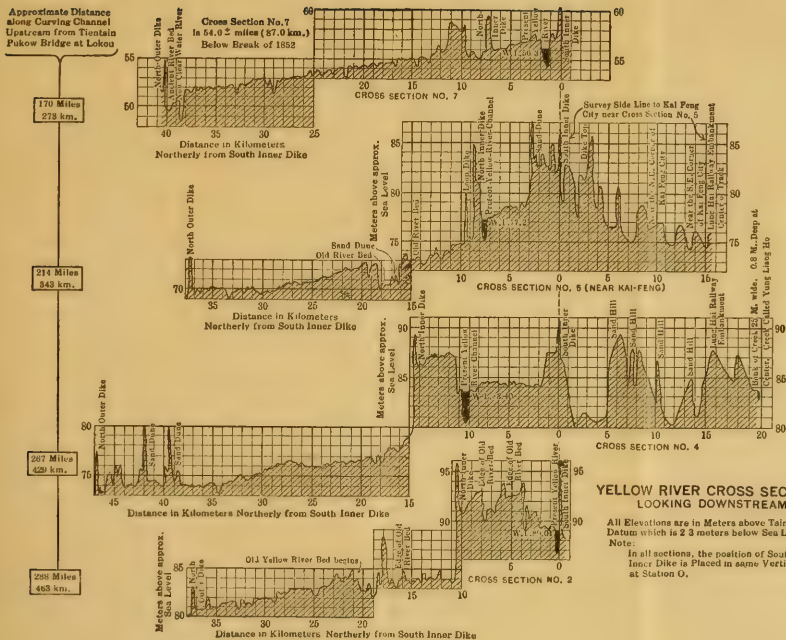
The three sections at the top of Fig. 12 are along the new course and those lower on the diagram are along the old course. All are drawn looking down stream and are arranged in regular order with the sections farthest down stream, or farthest east, at the top of the diagram.

These cross-sections surveyed in 1919 indicate that for about 80 miles of its length through the delta, or from the Peking-Hankow Railroad down to near the great break of 1851, the flood surface of the river is about 20 or 25 ft. higher than the level of the ground outside the inner dikes, and that the low-water surface is about 5 to 10 ft. higher than the ground outside the dikes; they also show that the normal bed of the river at low stages, averages about 5 ft. higher than the general level of the country, this bed probably having been raised a few feet by deposits of silt, to provide the needed slope for overcoming the friction of the increased length, as the river built its mouth farther out into the sea with the silt deposits of centuries.

Sections taken by the Kiang-huai Chinese surveyors along the abandoned channel of the Yellow River easterly from the Grand Canal in Kiang-su Province, in which the Yellow River flowed for 528 years until 1851, show that the super-elevation of the river here averaged about the same as that just described above the break of 1851, and thus curiously differs from the condition without super-elevation below the break of 1851, where the river has now been flowing for 70 years.

A longitudinal profile along the river surface and along the tops of both dikes also has been made up from this reconnaissance survey. This profile shows a remarkably uniform general slope of the river surface, except that there is a drop of about 10 ft. more than normal, within a few miles of the break of 1851, resulting in a largely increased slope for this distance. This is worthy of careful examination in the field, and why it has not cut back further and lessened this slope remains to be explained. Both the north and south river dikes are higher and thicker along the old course above the break of 1851, than along the new course below it.

In general, the accurate levels of 1919 confirm the statements of the English engineer, G. S. Morrison, and those of the Dutch engineers, Von Schermbeck and Visser, who visited the break of 1887 in 1888 and 1889, respectively, and reported the river bottom about 5 ft. above the level of the plain, and they disprove the statements of Gen. Wilson based on observations with only a hand-level, that no super-elevation of bed existed at the site of the break of 1851. None of these previous observers seems to have had the means for widely extended accurate leveling. Also, the speaker's reconnaissance disproved the old idea that there is a double set of good dikes, outer and inner, most of the way along the Yellow River, as a safeguard against the coursing of a flood far across the country, as in 1887.



YELLOW RIVER CROSS SECTIONS
LOOKING DOWNSTREAM

All Elevations are in Meters above Tsing-Tau Datum which is 2.3 meters below Sea Level

Note:
In all sections, the position of South Inner Dike is Placed in same Vertical at Station O.

Absence of Outer Dikes

Within these regions of super-elevation of river above the outside plain, which extend along the present course of the river for perhaps 80 miles down stream from the Peking-Hankow Railroad Bridge, greater danger is involved in the rupture of a dike, particularly on the south side where no outer line of dike exists; and it will be noted from Fig. 5, that most of the migrations have started on their new course from outbreaks in this region of super-elevation of bed. There is an outer line of dikes farther down stream, on the south side.

Along the north side of the river, near the apex of the delta, the so-called north outer dike of the present channel seems to be a south dike of a more ancient channel and below the break of 1851 the so-called south outer dike possibly may be one of the dikes of the river's course of 1194 to 1289; and this ancient abandoned river channel may have provided the site for an ancient canal described by the old records as existing in that vicinity. These outer dikes do not parallel closely the inner dikes, but are irregular and, in some localities, ten miles away from the inner dike. In general, the location or existence of this outer dike would seem at present to be more a matter of the accidental position of an ancient river course than of design for present-day protection. Nevertheless, these outer dikes sometimes serve a useful purpose in checking the course of a flood that has broken through the inner dike and an example of such a checking and turning back of a minor flood will be given subsequently.

Yellow River Flood Discharge

The flood discharge of the Yellow River is from 200 000 to 300 000 sec-ft. and perhaps more, a few times in each century. In 1919, a flood higher than any of the preceding ten years, had a peak discharge of about 280 000 sec-ft., which is about the same as the maximum flood volume of the Mississippi above the confluence of the Missouri. The ordinary low-water flow is about 10 000 sec-ft. and continues ordinarily from October to May. Although the discharge from low water to high water thus increases twenty-five-fold, the mean velocity is increased only about two and one-half times. The necessary increased area of cross-section is obtained partly by the rising and spreading of the waters, but largely also by the river digging its bed deeper and wider, as will be described later.

This flood volume of the Yellow River is only about one-tenth of the flood volume of the neighboring Yang-tze River, but, nevertheless, it is a mighty flood and continues high from one to two months. The main flood of the year comes at any time from July to September, and is caused mostly by rains or melting snows in the mountains and valleys, hundreds or thousands of miles up stream from the apex of the delta. Sometimes, brief important floods may come from heavy rains in the near-by mountains.

The log of a typical high flood, the highest of ten years, is given in Fig. 13. A good idea may be had of the variation from year to year in range, height, and duration, from the daily stage records, kept since about 1908

at the two railroad bridges, which show that the main flood may come at any time from July to September, but most commonly occurs in August, and continues for about five to eight weeks.

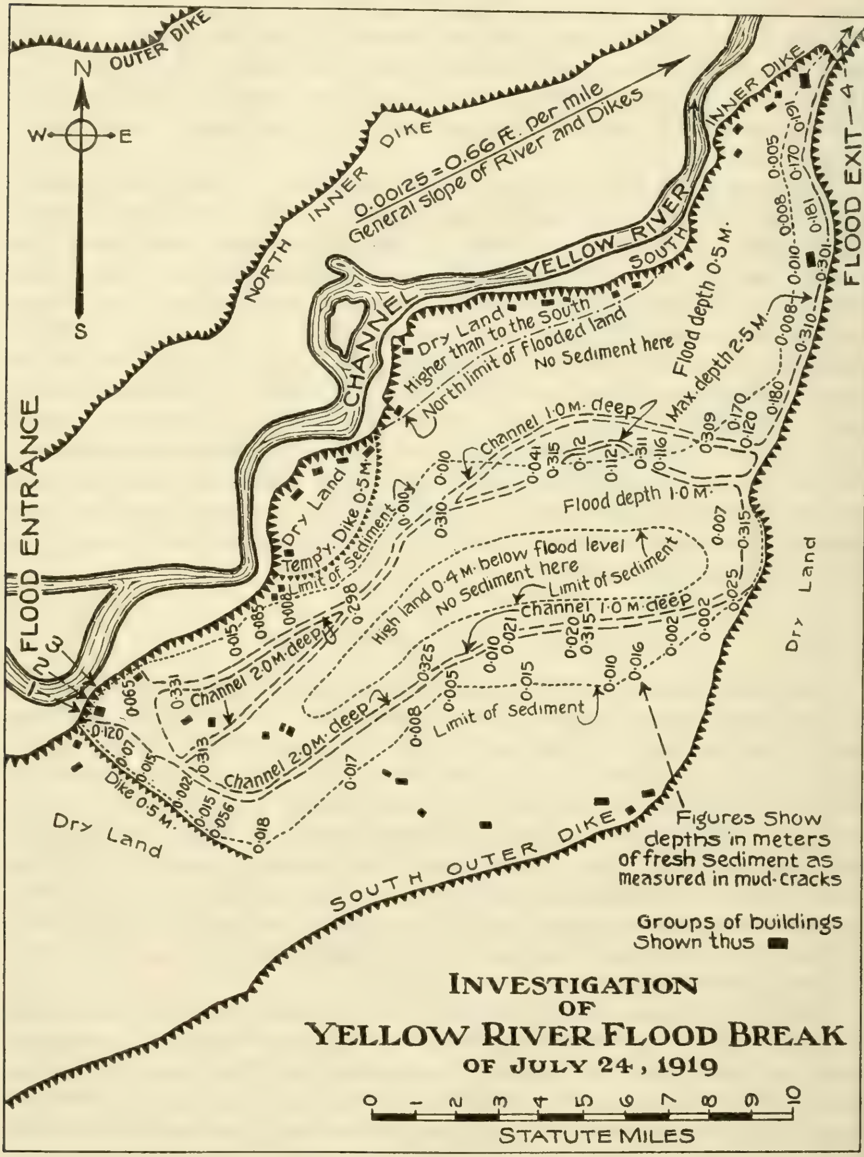


FIG. 13.

An isohyetal map of China (Fig. 25), is presented subsequently in this paper, in connection with Kiang-su problems; but rainfall studies give little aid on the flood problems of the Yellow River.

It is a remarkable fact that the Yellow River receives no tributaries within its long course of 400 miles through the delta, with the exception of the Ta-ching Ho, the bed of which it usurped in 1851. Obviously, they could not get in through the dikes. Moreover, here, as in most deltas, and as shown in Plate XX, the river flows along a sort of crest, with the ground at right angles on both sides falling away on a slope, imperceptible to the eye, of only 6 in. to 1 ft. per mile. This outward slope of the flat delta cone obviously leads away from the river, the water pouring out through a break in the dike. This makes the control of the river, or the repair of a breach in a dike, particularly difficult, and gives to the Yellow River outbreaks, spreading sidewise, down a delta cone, a character different from those of an ordinary river coursing down a valley.

When a flood makes a complete breach of a dike and escapes in large volume to the lower level of the ground outside, it quickly cuts a deep channel at the point of exit, which soon may become a gap a mile wide, and it is a serious matter to get the river back into its bed, particularly in localities where the bed is a few feet higher than the ground outside the dikes. Once in each few hundred years it has proved impossible to force the return of the river to its previous course, as in 1851-53. It came near to being impossible in 1887.

Remarkable ingenuity and skill, gained from centuries of experience, is shown in closing a large breach. In general the method of the Chinese engineers, as described to the speaker by Messrs. Charles K. Edmunds and F. W. Tyler, the latter a retired sea captain who was for many years in the Chinese Coast Inspection Service of the Maritime Customs, is to narrow the breach by building out from the two ends with a current-resisting structure, skillfully made of crossed bundles of large millet stalks (Kao-liang) bound with bamboo or straw ropes, pinned down by small stakes, packed with river silt, and commonly weighted with more or less loose stone of about 1 cu. ft. in volume. Meanwhile, short spur-dikes at a slight angle down stream are built to deflect the current away from the new work. It is an extraordinary tribute to their skill that by the use of such weak and perishable materials as Kao-liang stalks and straw ropes, they can narrow the gap to about 100 yd. after being aided by the subsidence of the flood. This Kao-liang or giant millet has a stalk about 6 ft. tall and $\frac{3}{4}$ in. in diameter, with a thickly matted bunch of roots about 5 in. in diameter. It resembles the sorghum plant in shape and size. The bunch of roots is placed outward, against the impinging current.

For the final closure, many great ropes of bamboo fiber are stretched across the gap, which finally is plugged either by lowering into it, or by floating into it, a sort of gigantic thick raft, skillfully built of great bundles of millet stalks bound with bamboo ropes and held and guided by perhaps 100 bamboo cables, each nearly 3 in. in diameter, all constituting an exceedingly bold operation. As soon as the current has been thus checked, a thick reinforcing embankment of earth and stones is rapidly constructed front and rear, by thousands of men with baskets of earth; which next is protected by stone rip-rap, and, meanwhile, the river is deflected away from the new embankment by the construction of spur-dikes.

Some Noteworthy Outbreaks

By way of further demonstration of the vast importance of finding a method of solving China's flood problems to the many millions of people inhabiting this vast delta between Kai-feng, Tientsin, and Chin-kiang (possibly more than the total population in the Buffalo-Boston-Washington triangle, for the great city populations in New York, Boston, Buffalo, etc., are outnumbered in the density of China's farm population), the following cases of serious floods from outbreak of the Yellow River are briefly stated. So recent is the opening up of that vast country to foreign engineering inspection and so imperfect have been the means of transmitting information, that the facts have been little known to the outside world.

The three most noteworthy outbreaks of the Yellow River in recent years of which details are available are as follows:

First.—The great break of 70 years ago, which changed the river's course for 270 miles, as shown in Fig. 5. This break occurred during the summer flood of 1851, but the water seems not to have been completely diverted into the new channel until 1853. The new course of this flood laid waste a stretch of prosperous country about 10 to 20 miles wide, and about 140 miles long, or nearly 2 000 sq. miles, and the escaping waters were not gathered into a narrow channel between dikes for this 140 miles below the break until about a quarter of a century had passed. No record is now known of the thousands of people who perished, or of the great value of the property ruined and the fertile farms destroyed along its path.

This diversion from the course that had been followed for 628 years also caused disaster to many thousands of farmers living along the deserted river bed by depriving them of their previous water supply.

Second.—The break of 35 years ago, which cost more than 1 000 000 lives and a vast property damage, came near causing a permanent diversion and was repaired after 1½ years of mighty efforts and great expenditure.

Third.—The break of 1903, about 13 miles below Tsi-nan (or "Chinan"), which is described by Capt. W. F. Tyler in his pamphlet* on the Yellow River. This outbreak deposited a bed of silt said to be from 3 to 8 ft. in thickness, over much of an inundated area of about 200 sq. miles, and caused such terrible distress as to call for organization of famine relief from foreign sources.

Details of the Great Break of 1851

It is said that foreigners first heard of this break 6 years after it occurred, and that 11 more years elapsed before anything definite about the cause of the river's change of course was known to the outside world. The first visit of a European to learn what had happened in 1851, was made 17 years after the catastrophe, by an English merchant of scientific education, residing at Shanghai, Mr. Ney Elias, who visited the new course and the scene of the break in October, 1868, and reported his findings to the Royal Geographic Society of England, which published his account.†

* Published in 1906, by the Maritime Customs Office at Shanghai.

† *Journal,* Royal Geographic Soc., Vol. XL (May 5th, 1871).

For many miles up stream from the site of the former course of the Grand Canal, he found the new river flowing irregularly over a strip of country about 10 or 12 miles in width, which had the appearance of a field, inundated and laid waste, rather than that of an ordinary river channel. The strip, thus laid waste, probably was 90 miles long. From 20 to 52 miles up stream, from the break, the river was flowing in a single, well-defined channel, where the shifting currents had deposited low, wide embankments of silt, perhaps 6 to 10 ft. deep, from which protruded half buried houses and temples. The river was flowing between the newly-made banks of silt deposit about 10 ft. high, with its bed at about the previous level of the country. Between the hills of Yu-shan and Chiau-kou, at the northwest corner of the Shantung Mountains, where the escaping waters found and usurped the ancient channel of the Ta-ching Ho, the waters were again gathered together and flowed to the sea, greatly swelling the volume of the Ta-ching River. Some reports state that the silt-laden water raised its deep-cut bed by deposits of silt; other observers, including Mr. Elias, reported that the added flow had cut the Ta-ching wider and deeper. Probably the discrepancy was due to different localities observed. Mr. Elias proceeded down the Ta-ching Ho to where it entered the sea to learn of its possible availability for navigation. The lower 20 miles was found to be flowing through low uninhabited mud flats, deposited from the river's burden of silt. The report by Mr. Elias is an admirably clear description, which impresses one with the author's keenness as an observer.

Mr. Elias made a second visit for the purpose of exploring a new connection said to have been established in 1868, between the Yellow River and the Yang-tze *via* the Sha Ho and Huai River, through a break in the south dike 50 miles up stream from the City of Kai-feng. He found, however, that the breach had been repaired and that boat navigation was stopped early in 1870, after more than a year of flow through a breach 1 mile wide, but not deep. Mr. Elias, in his second paper, discusses the merits of turning the Yellow River back into the course it had followed prior to 1851, and calls attention to the great hardship that had been suffered by the large population along the old course of the river, in being deprived of water for irrigation and navigation. A large migration of this river thus brings disaster to millions of people along both the old and the new courses, because this fertile delta is populated in many places so densely that a farm of 3 to 5 acres has to provide the support of a family.

About ten years later, the new course was visited by a prominent English engineer, Mr. G. J. Morrison, who made an outline survey and map. The multitude of shallow shifting irregular streams flooding 10 to 15 miles in width, found by Mr. Elias, had then been gathered into a single stream between dikes, or had gathered itself, into this single, narrow channel by its erosion of its bed slightly below the general level of the plain as now found and shown in the top sections of Fig. 12.

An outline map of the region near the break of 1851, surveyed early in 1919, is given in Fig. 14. The speaker visited this locality in December, 1919, and found the landscape so broad and of such low relief that it was difficult for one in the field to take in the relation of one part to another. Although the

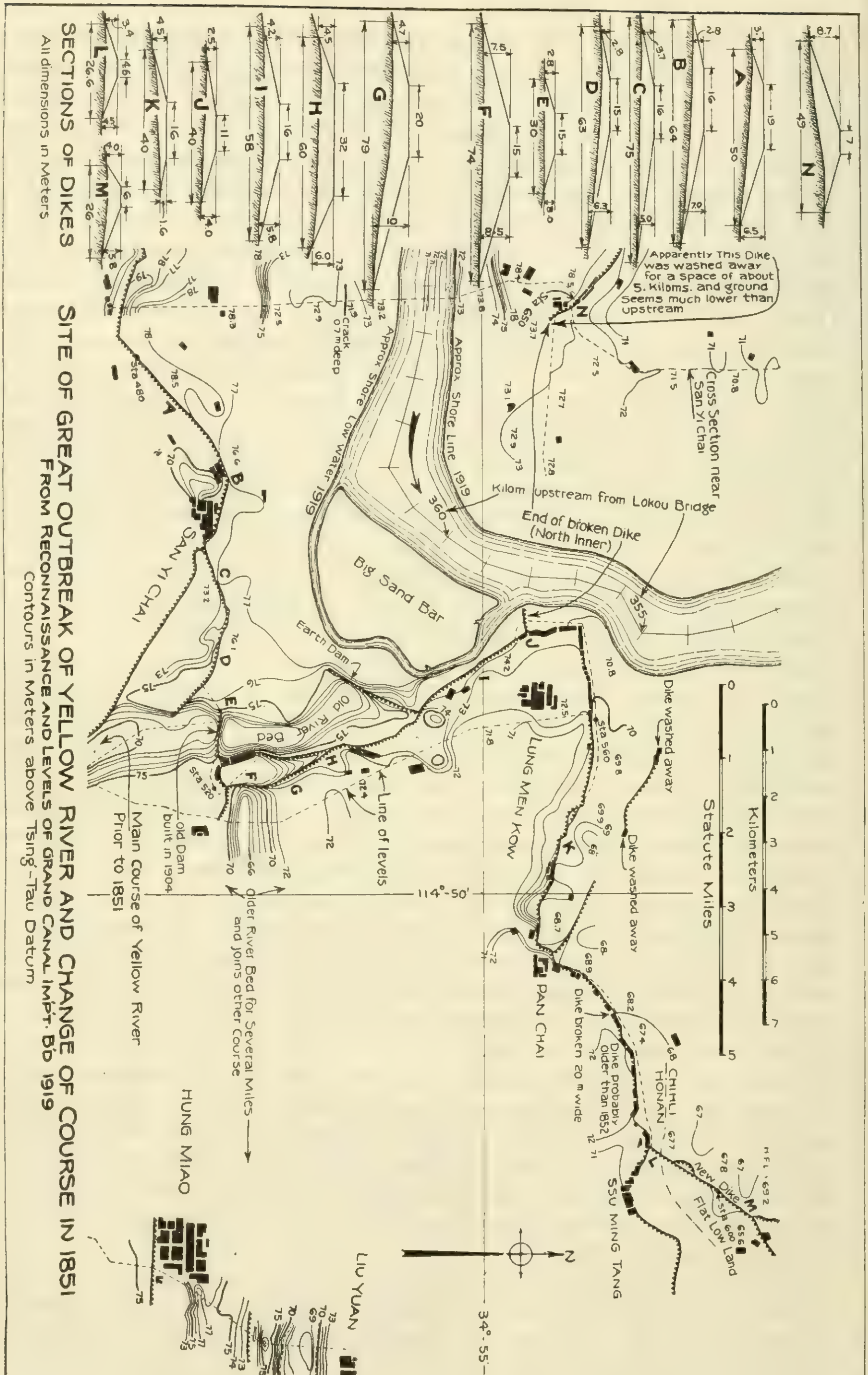

SITE OF GREAT OUTBREAK OF YELLOW RIVER AND CHANGE OF COURSE IN 1851
FROM RECONNAISSANCE AND LEVELS OF GRAND CANAL IMP'T. B'D 1919
Contours in Meters above Tsing-Tau Datum
SECTIONS OF DIKES
All dimensions in Meters
Kilometers
Statute Miles
Apparently This Dike was washed away for a space of about 5. Kiloms. and ground Seems much lower than upstream
Cross Section near San Yi Chai
Approx. Shore Line 1919
Approx. Shore Low water 1919
Kilom upstream from Lokou Bridge
End of broken Dike (North Inner)
Big Sand Bar
Earth Dam
Old River Bed
Line of levels
Crack 0.7 m deep
SAN YI CHAI
LUNG MEN KOW
PAN CHAI
CHIHLI
HONAN
SSU MING TANG
New Dike
Flat Low Land
Dike washed away
Dike broken 20 m wide
Dike probably older than 1852
Old Dam built in 1904
Main course of Yellow River Prior to 1851
Older River Bed for Several Miles and joins other Course
HUNG MIAO
LIU YUAN
114°-50'
34°-55'

FIG. 14.

chief events are plain, it will require a much closer and more detailed topographic map than is yet available, and a week in the field, map in hand, for tracing out in detail just what happened where the river changed its course. The river, breaking out to the north, found a country about 12 ft. lower in elevation than its former bed, over which it could flow, and over this, in ill-defined shifting channels the flood ultimately reached the Valley of the Ta-ching Ho, within which, the records show, it had flowed for at least about 80 miles, perhaps reaching the sea by the Hsiao-ching Ho, about six centuries before.

As stated previously, the escaping flood of 1851 usurped this Ta-ching channel and in the course of 50 years, filled some miles in length of its bed with silt almost to the general level of the ancient delta plain, the depth of new silt thus deposited at Lo-kou being about 12 ft., according to borings made for the railroad bridge. Possibly, the "Ta-ching" or "clear-water" river, which, although small, sometimes gives brief violent floods, by six centuries of effort had scoured this part of the channel bed below the elevation that it possessed when occupied by the Yellow River from 1194 to 1289.

Some Details of the Flood of 1887

The outbreak of 1887, already mentioned, has been described by the English engineer, G. J. Morrison.* He says, "the breach through the dike was a full mile in width and the flood swept onward toward Hun-tze Lake and the Huai River, inundating a strip variously estimated at 20 to 50 miles in width, carrying away houses and villages and parts of walled cities."

Mr. Morrison reports that the breach occurred on September 29th, 1887, but was so great that it had not been closed when the next year's flood came in June, earlier than expected. All repair work of the previous months, which had cost a vast sum, was wasted, but the Chinese began resolutely again and, declining to follow foreign advice, adhered to their own ancient methods. At the time of his visit (September 1st, 1888), they had narrowed the gap to 400 ft. through which flowed an eddying current of about 7 miles per hour (10 ft. per sec.). He concluded that the original bed of the river was about 4 ft. higher than the level of the plain outside. The flood surface, of course, was much higher. His soundings showed a depth of 60 to 70 ft. in the breach and a deep gully for some distance inside and outside.

Mr. Morrison reports further, that the new banks were faced with Kao-liang stalks firmly packed in earth and that these millet stalks were brought, in some cases, by wheelbarrows from farms 20 miles away and that the earth for the new dike was all brought in baskets.

The final closure was made by a mattress of Kao-liang stalks and earth thoroughly bound together, suspended from many great bamboo fiber ropes across the breach, and lowered into place. The closure was completed on February 2d, 1889, and was greatly aided by a low stage of the river and by a strong ice cover.

Fig. 15 shows the interior of a temple that celebrates the closure of the break of 1887. Gordon Cumming† describes this flood as covering a strip 30

* *Engineering* (London), March 3d, 1893.

† "The Leisure Hour", pub. about 1888.

miles wide, having an area of 10 000 sq. miles, and flooding or destroying 3 000 large villages, with a probable loss of life of 7 000 000; and states that the flood continued high for two months and that the Chinese Imperial Treasury donated $2 500 000 for relief.

The speaker visited the site in December, 1919, and he has profound respect for the skill that under such difficulties could achieve success with such poor structural materials, such simple tools, and nothing but non-cohesive, fine sand with which to build this vast thick dike 30 ft. above the plain. Fig. 10 shows the site as the speaker found it, looking outside the dike across the gully of the flood.

Some Details of the Flood of 1902

Some features of the outbreak of 1902-03, on the lower river, are given in Capt. Tyler's report on the Yellow River, mentioned elsewhere in this paper, and some of the chief items of interest have been quoted previously. The breach occurred on September 12th, 1902, near the end of 2 months of flood and continued 6 months and 4 days. An attempt at closure on January 2d, 1903, soon after the flood had subsided, was frustrated by the capsizing of the mattress raft with which it was planned to close the final gap. Capt. Tyler states that in damage, maintenance, and expense of closing this breach, the Yellow River cost Shantung Province $2 000 000 in 1902. He attempted an estimate of the vast volume of silt deposited, after observing a few localities and seeking information from the natives regarding the other localities. He concluded that an average depth of 3 ft. over the 200 sq. miles might perhaps be true. A 3-ft. depth on 200 sq. miles would be about 400 000 acre-ft., a quantity so vast that the speaker cannot quite credit it after computing the probable discharge of water and its probable proportion of silt, carried at various stages, and considering that the outflow was mostly after the flood had largely subsided.

The colored illustrations of Kao-liang dike protection and groynes in the little book by Capt. Tyler,* are the finest that the speaker has ever seen. The book contains many interesting and valuable data regarding the Yellow River between Lo-kou and the sea. By sounding, Capt. Tyler found a maximum depth of 40 ft. in the channel pools in the low-water season and in some places a depth as great as 30 ft. against the bank, with slopes of 45%, of partly decomposed Kao-liang, to which he recommended that a facing of rip-rap be applied as providing the most efficient and economical maintenance. His chief recommendation was that the low-water channel be straightened by groynes and by silting in the eddies below the groynes, and that the erosive power of the river at all seasons, should be thus prevented from acting on the main dikes. He also suggested a system of temporary detention reservoirs along the river in the upper part of the delta, in which flood water might be detained and silt impounded for raising the general elevation of the ground.

Capt. Tyler states that he has recently found to be unreliable some of the information given him in 1902 as to the rate of the filling up of the Ta-ching

* "Notes on the Yellow River", pub. by the Imperial Maritime Customs, Shanghai, 1906.

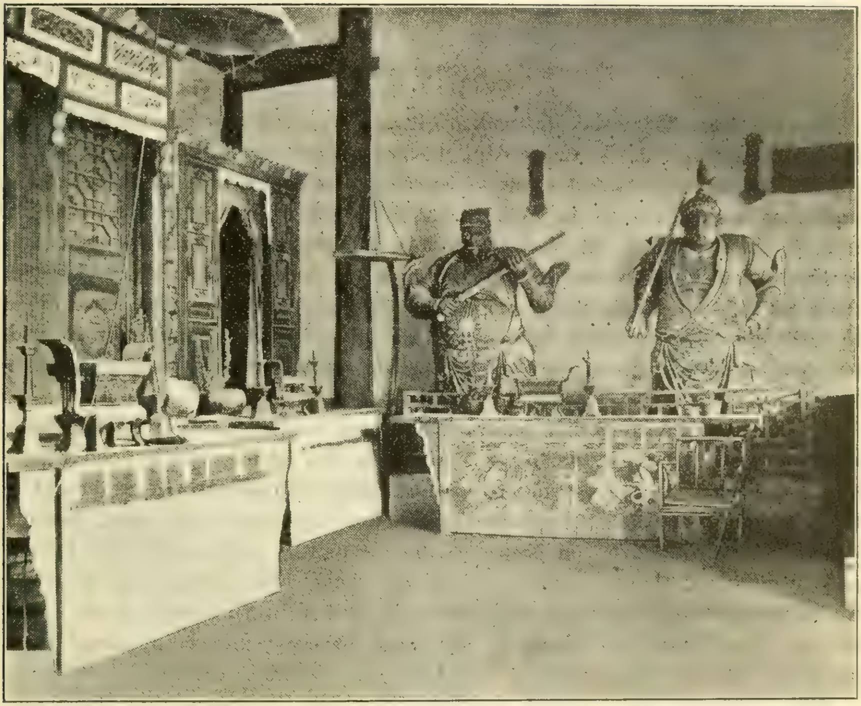


FIG. 15.—INTERIOR OF CHINESE TEMPLE WHICH COMMEMORATES CLOSURE OF BREAK OF FLOOD OF 1887.

Ho since the incursion of the Yellow River, which he quoted in this report of 1906. The actual filling is much less. He gives much other interesting general information of the Yellow River down stream from the crossing of the Tientsin-Pukow Railroad. About 30 years after the incursion of the Yellow River, and after the bed of the old Ta-ching Channel had become more or less raised, dikes were built from 3 to 7 miles apart, enclosing the enlarged river. Later, the riparian farmers, desiring to reclaim the land, were permitted to build, without much system or control, inner dikes only about a mile apart. These dikes, in the course of time, became the main dikes and the outer dikes were neglected. The river floods now rise about 15 ft. above the general delta level and are restrained by the inner dikes.

Floods Along the New Course

Down stream from the outbreak of 1851, along the new course, as far as the confluence of the Ta-ching Ho, the surface of the Yellow River, when not in flood, is not elevated above the surrounding country, as has been previously stated and as is shown by sections at the top of Fig. 12. The outbreak of 1919, shown by Fig. 13, is of interest in illustrating the small danger of a permanent outbreak in that part of the river the bed of which is not elevated above the surrounding country, and in showing the efficacy of the outer dike. Nevertheless, this particular flood spoiled the crops on 125 sq. miles, surrounded 560 small villages, drove out 217 000 people, and destroyed property worth $350 000.

In this case the inner dike probably had been neglected, a gap having been worn in the road across the top was found by the rapidly rising flood which was higher than any of the preceding ten years. The outrush of water cut a deep channel at the point of exit and then spread in a broad thin sheet, flowing southward, ruining growing crops on the intensively cultivated little farms, until intercepted about 8 miles away by the south outer dike, along which it flowed about 20 miles parallel with the main stream, until caught in an angle between dikes, where, by reason of the inner, or river, dike being lower than the cross-dike, the flood broke its way back into the main channel.

Fig. 13 shows some typical channels, in which it appears that the water tends to gather itself by means of its power to erode the soil and carry it in suspension; but the general effect of these outbreaks is to spread a broad stratum of sediment over nearly all the country inundated.

A peculiarity of the Yellow River sediment is its remarkably rapid and almost complete subsidence in still or slow moving water, therefore this stratum is thin under the pools farthest removed. Care was taken to measure the depths at many places and the results are shown in typical places on the map. In general, the depth over the local surface was about 1 in. and along the gullies about 1 ft. A rough estimate gave a total volume of about 12 000 acre-ft. of sediment deposited on about 60 000 acres. The Chinese engineer who made this reconnaissance, found difficulty in measuring the precise depth of sediment and, obviously, saw only a small part of the sub-

merged 125 sq. miles in his rapid trip around the edges and down the gullies; the figures, therefore, on Fig. 13, are to be considered illustrative and not as a definite measure of the whole. The average depth was only one-fifteenth of that reported by Capt. Tyler from the outbreak of 1902, notwithstanding the water at the time of this 1919 break was carrying, by weight, about 4% of sediment; but here, in 1919, only a small portion, perhaps 20%, escaped from the main channel and this stopped flowing as soon as the river stage fell below the level of the country; whereas, in 1902, the whole river broke out, and continued out of its channel for six months. These two divergent instances are quoted to illustrate that one must not be hasty in generalizing about silt deposits from outbreaks until all the facts are known.

Ancient Records

A research among the city, provincial, and National records, probably would give a story of hundreds of outbreaks and show that at one place or another along this 400 miles of the Yellow River's course, for several thousand years, the population far and wide over this vast delta has lived in great danger, which danger exists to-day.

To illustrate the care with which the Chinese keep records in even the smaller towns: At the little Town of Lan-yi, near the great break of 1851, the speaker asked the magistrate about previous breaks, and a few hours later he had reviewed the town records for the preceding 200 years and presented a concise statement of about a dozen important floods or outbreaks in that immediate vicinity.

The Finje Report on the Yellow River

Because of the heavy floods in the Yellow River delta in the autumn of 1887, a reconnaissance was made in 1889 of the Yellow River through the delta, at the request of the Imperial Government, by two Dutch engineers, Von Schermbeck and Visser, and under the general counsel of Mr. Finje von Salverda, an eminent Dutch authority on rivers and harbors. Mr. Finje did not himself visit China, but wrote a sixty-page introduction, comprising many observations by Richthofen and sundry philosophical discussions. The interesting report by his agents adds little precise information to that given by Elias and Morrison, but confirms their statements. Messrs. Visser and Von Schermbeck express opinions favorable to training the river, and state that a limiting of width might be advisable, noting that at Tsi Ho, a few miles above Lo-kou, the river got along very well in a channel only 1 770 ft. wide. They agree with Mr. Morrison that, at the break of 1887, the bottom of the Yellow River originally was about 3 to 5 ft. higher than the ground outside the dikes. They record their observation, which is confirmed by the speaker's surveys, that "the whole of the new course from the great breach of 1852, appears to be below the general level of the country immediately adjacent to the river" and list sixteen outbreaks through the Yellow River dikes in 16 years in Shantung and Chihli, which affect Shantung Province.

Past and Present Safeguards against Yellow River Floods

From time immemorial, the maintenance of the Yellow River dikes has been one of the principal functions of the Government of each Province. Capt. Tyler states that until 1901 the whole river was in charge of one office, the River Viceroy, and that since then each Provincial Chief is responsible for the section of river within his Province. The conditions and methods described by Capt. Tyler doubtless prevail largely to-day. In Shantung, in 1903, he found three river Taotais controlling, respectively, the upper, middle, and lower thirds, and each Taotai had under him six military captains who were practically the resident engineers. Taotais and captains had been brought up from youth on this river work, and he met several who had been employed on it for 50 years, and who remembered conditions along the Taching Ho prior to the invasion of its bed by the Yellow River, earnest, careful men eager for new ideas, but extremely conservative in following ancient practice. Each captain had charge of only one side of the river. In protecting his bank, if he deflected the river against the opposite bank, that was the affair of the opposite captain. The speaker presumes that the care given under the Imperial System may have relaxed in some sections, with the disturbed political conditions of recent years.

In 1906,* Capt. Tyler estimated the expenditures on the Yellow River at 3 500 000 taels annually, equivalent to about $2 500 000. He estimated the annual destruction of property by the river's floods at about $1 000 000, without including the great catastrophes of 1851 and 1887.

Capt. Tyler's report gives an interesting account of current practice on the lower river down stream from the Tientsin-Pukow Railroad in 1903, showing forms of shore protection and a method of closing a break. The groynes shown by him are constructed from Kao-liang, or millet, stalks, but their purpose is the same as that of the stone groyne shown in Fig. 8. The shore protection, that the natives call the "fish-scale" type, is built also of millet stalks, tied, pinned, and packed together with earth tamped into the interstices. The "fish-scale" or serrated form of Kao-liang bank protection is considered by Tyler as a deliberate design, in preference to a smooth face, and that this preference is based on experience with this perishable material, which has a stalk about 6 ft. tall, that is weak and composed mostly of pith, but which has a mat of firm strong roots that are placed outward in the embankment to receive the impact of the current. In course of a year or two, the Kao-liang rots as the river rises and falls and a "pakwerk", 25 ft. high, may settle 4 to 8 ft. As long as the river persists in its attack on this particular piece of bank the protection of Kao-liang is renewed by placing more on at the top. The mat of Kao-liang that is settled and compressed below the low-water level may last a long time. In many places, the Kao-liang groyne is faced later with a rip-rap of stones averaging 1 to 2 cu. ft. in volume.

No protection works face the earthen main dike, except where the river now impinges, or where in former years it has attempted to cut through.

* "Notes on the Yellow River", p. 10, Shanghai, 1906.

The Yellow River Digs Deeply in Floods

The remarkable erosive action on the bed of the Yellow River and the vast quantity of the fine-grained silt that this river can carry in a day are "great forces of Nature" that the speaker would propose to "use for the benefit and convenience of man," thus fulfilling the traditions of Civil Engineering as defined by Tredgold in the charter of the Institution of Civil Engineers of Great Britain.

In the course of investigations on the channel of the Yellow River* preliminary to designing its crossing by the Grand Canal, it has been found that, during a flood, this river digs its channel deeper and wider in a most remarkable way, and thereby gains at the bottom of the normal river bed much of the additional area of cross-section required by the enlarged volume.

As the flood subsides, silt is deposited, refilling the channel and raising the bed to its former elevation and contour. The speaker was on the lookout for this phenomenon, because years ago his attention had been called by Horace Ropes, M. Am. Soc. C. E., to a similar phenomenon in certain rivers of New Mexico and Arizona; also similar erosion and refill had been observed on the Colorado at Yuma, Ariz., which the speaker had visited and which at that point and below greatly resembles the Yellow River in its silt burden.

Similar erosion and refill also has been noted by English bridge engineers on certain rivers in India, but in none of these cases previously published have the observations been so extensive in following the changes through the rise and fall of a flood, or so carefully confirmed at every stage, as in these measurements of velocity, depth, and silt burden, made at four stations along the Yellow River many miles apart.

This fact of the readiness of the Yellow River to scour a deeper channel when properly confined between dikes, taken in connection with the practically unlimited depth of the bed of silt in which it can dig, together with the hydraulic law of increase of velocity with increase of depth, makes it feasible to maintain a narrow channel at all stages from drought to flood, that can quickly adjust itself to carry a large volume of flood water. Before discussing the training of the river in a new straight channel, however, the proof of the facts about erosion and refill will be presented.

For frequently measuring the depth, width, velocity, and discharge of the Yellow River, gauging stations were established by the Grand Canal Improvement Board, in 1918-19, at the following places:

(1) Near the ancient canal line at Shih-chia-wa.
(2) At a possible site for a new crossing at Wei-chia-shan, 13 miles farther down stream.
(3) At another site for canal crossing, 6 miles farther down stream, at Chian-kou opposite to Yu-Shan.

At each of these places, systematic current-meter gaugings and soundings were made from the low-water stage in the spring through the various rising and falling stages of a flood greater than any of the preceding ten years and

* The speaker has in preparation a paper on the "Hydraulics of the Yellow River" in which the characteristics of this stream are discussed in greater detail than space permits in this paper.

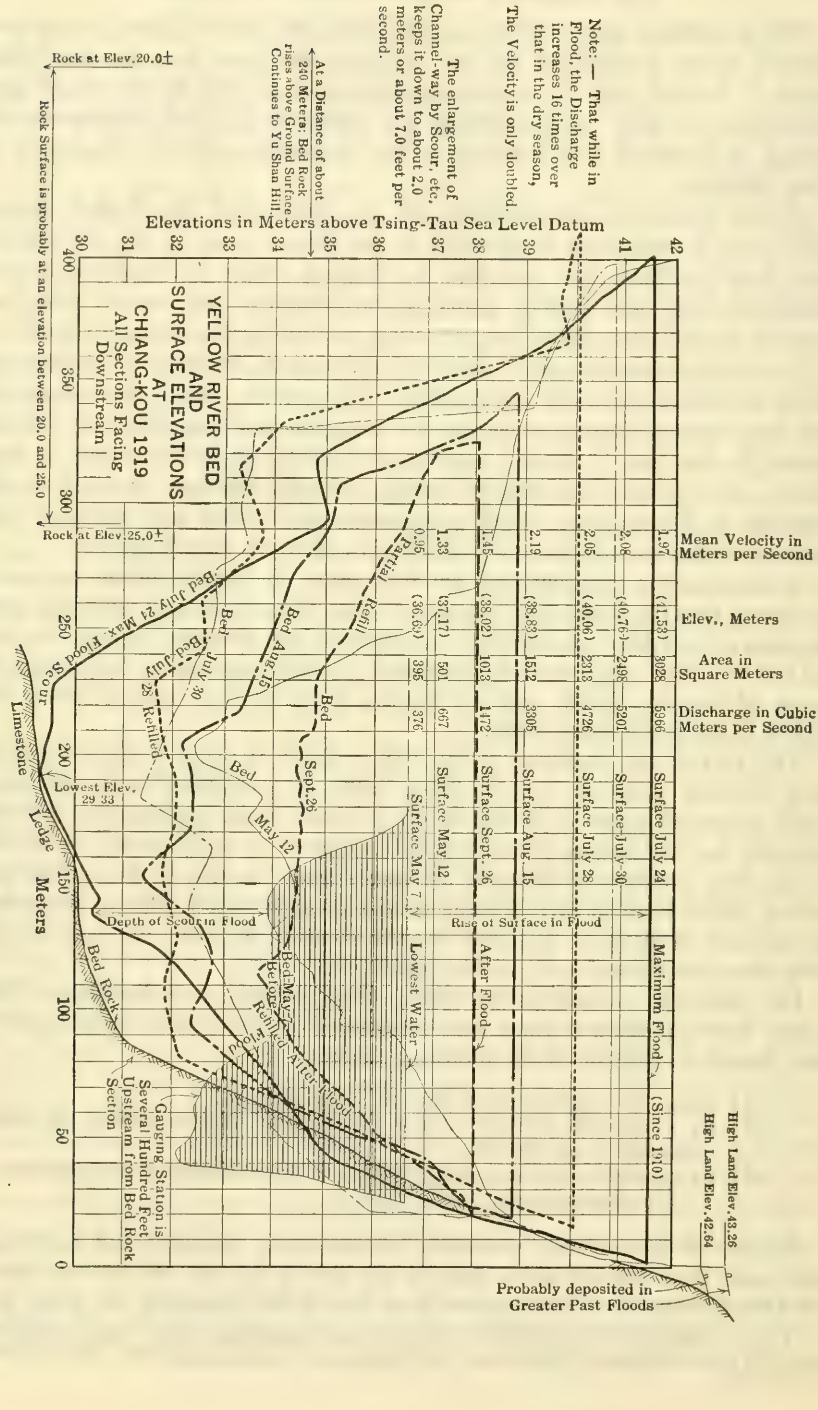

Note: — That while in Flood, the Discharge increases 16 times over that in the dry season, The Velocity is only doubled.
The enlargement of Channel-way by Scour, etc. keeps it down to about 2.0 meters or about 7.0 feet per second.
At a Distance of about 240 Meters: Bed Rock rises above Ground Surface Continues to Yu Shan Hill.
Rock at Elev. 20.0±
Rock Surface is probably at an elevation between 20.0 and 25.0
Rock at Elev. 25.0±
Elevations in Meters above Tsing-Tau Sea Level Datum
YELLOW RIVER BED AND SURFACE ELEVATIONS AT CHIANG-KOU 1919
All Sections Facing Downstream
Mean Velocity in Meters per Second
Elev., Meters
Area in Square Meters
Discharge in Cubic Meters per Second
Surface July 24
Surface July 30
Surface July 28
Surface Aug. 15
Surface Sept. 26
Surface May 12
Surface May 7
Bed July 21 Max. Flood Scour
Bed July 28 Refilled
Bed July 30
Bed Aug. 15
Partial Refill
Bed Sept. 26
Bed May 12
Bed May 7 Before Flood
Refilled After Flood
Lowest Elev. 29.33
Depth of Scour in Flood
Rise of Surface in Flood
Lowest Water
After Flood
Maximum Flood (Since 1910)
Limestone Ledge
Bed Rock
Gauging Station is Several Hundred Feet Upstream from Bed Rock Section
High Land Elev. 43.26
High Land Elev. 42.64
Probably deposited in Greater Past Floods
Meters

FIG. 16

extending into the autumn when the river had nearly fallen to its normal stage.

(4) Meanwhile, the Chihli River Commission established frequent gaugings at the bridge of the Tientsin-Pukow Railroad about 70 miles down stream from Chian-kou.

(5) A station, about 300 miles up stream from Station No. 1, within the hilly country up stream from the delta, was also established by the Chihli River Commission for obtaining a rating curve for a cross-section where the bottom of the river was supposed to be stable, hard, and not subject to scour.

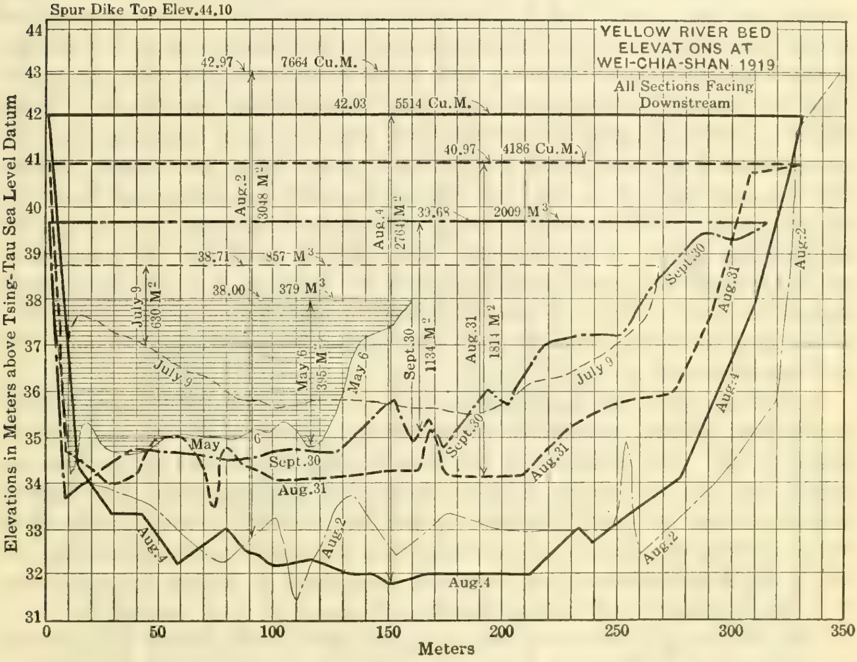


FIG. 17.

These several cross-sections were purposely selected as having different characteristics of outline and velocity of approach, with a view to using each as a check on the other and to guard against being misled by abnormal conditions at any one location.

The results of soundings and gaugings at all four locations confirmed one another in a most satisfactory way. The more important results for two of these stations are shown in Figs. 16 and 17, in which, for clearness there have been plotted only a few typical cross-section lines for different stages. In every case, as the discharge increased, the river dug its bed enough deeper and wider so that with the rise and spread at the top, the mean velocity of the whole cross-section never rose above about 2½ m. (or about 8 ft.) per sec. As the flood subsided, the space thus excavated was refilled with a most remarkable constancy of relation.

In many other gaugings of streams within the China delta plain, the speaker has found that the mean velocity of the entire cross-section seldom rises to more than 6 or 8 ft. per sec., in floods. In other words, given a material that can be eroded, the current digs out the bed and carries off the excavated material in suspension, until it has made for itself a comfortable channel in which it does not have to hurry.

Some careful tests were made for finding the truth about the oft-quoted statement that near the bottom of this and other streams heavily laden with silt, there is a flowing stream of soft, semi-fluid mud 1 ft. or more in thickness.

The silt sampling by means of pump and pipe immersed at various depths showed nothing of that kind, but in order to be sure about it the speaker had special tests made at several points near mid-channel under the Lo-kou Bridge of the Tientsin-Pukow Railroad, with a horizontal flat iron disk, 14 in. in diameter, screwed to the bottom of a long vertical iron pipe about 1 in. in diameter, which reached above water and was used as a sounding rod, and manipulated from a boat held in position by ropes from the bridge. Within this iron pipe was a $\frac{1}{2}$-in. steel rod sliding up and down, projecting above the top of the pipe, which could be thrust several feet into the river bottom by applying the weight of the observer. The observer could feel the consistency and hardness of the river bed plainly with the disk and rod, and many trials showed it about as firm and sharply defined in mid-channel as in depths of 2 or 3 ft. near the shore. The existence of a flowing bottom stratum of semi-fluid mud was disproved.

Soundings were also made with a thin wire line and flat-bottomed, boat-shaped lead weights, capable of combination to give 30, 60, 90, and 120 lb. weight in air. The elevation of the river bottom determined by the heaviest weight was not materially different from that determined by the lightest weight, or from the depth measured by the disk and stiff sounding rod; all of which confirms the speaker in the belief that the depths measured in Figs. 16 and 17 are dependable and that there was, in general, no serious error or excess from the bellying out of the sounding line in the swift flood current.

The silt content that can be carried in the water of the Yellow River within the delta region is found to be closely related to the mean velocity. As the velocity increases beyond, say, 2 or 3 ft. per sec., more silt is taken from the bed into suspension, but it is dropped promptly when the mean velocity decreases. This is illustrated in Fig. 18, in which are given lines showing the daily height of the water, the rate of discharge, the percentage of silt by weight, and the mean elevation of the river bed for a width of about 200 ft. near mid-channel, each of these lines being a composite made up from the measurements at the three principal gauging stations, all of which were in excellent general agreement.

It will be noted that there is a lag of from 7 to 10 days from the discharge curve to the line showing the erosion and refill of the bed. It would be interesting to have similar curves from gauging stations located, respectively, near the up-stream and near the down-stream end of the channel through the delta, or, say, 250 miles apart, for observing the influence of the quantity of silt taken into suspension from this erosion day by day, or week by week. All

of the speaker's observations tended to show that this silt picked up along the way, forms only a small part of the entire silt burden brought down through the delta from the erosion of the vast loess hills of Shansi and other Provinces far up stream.

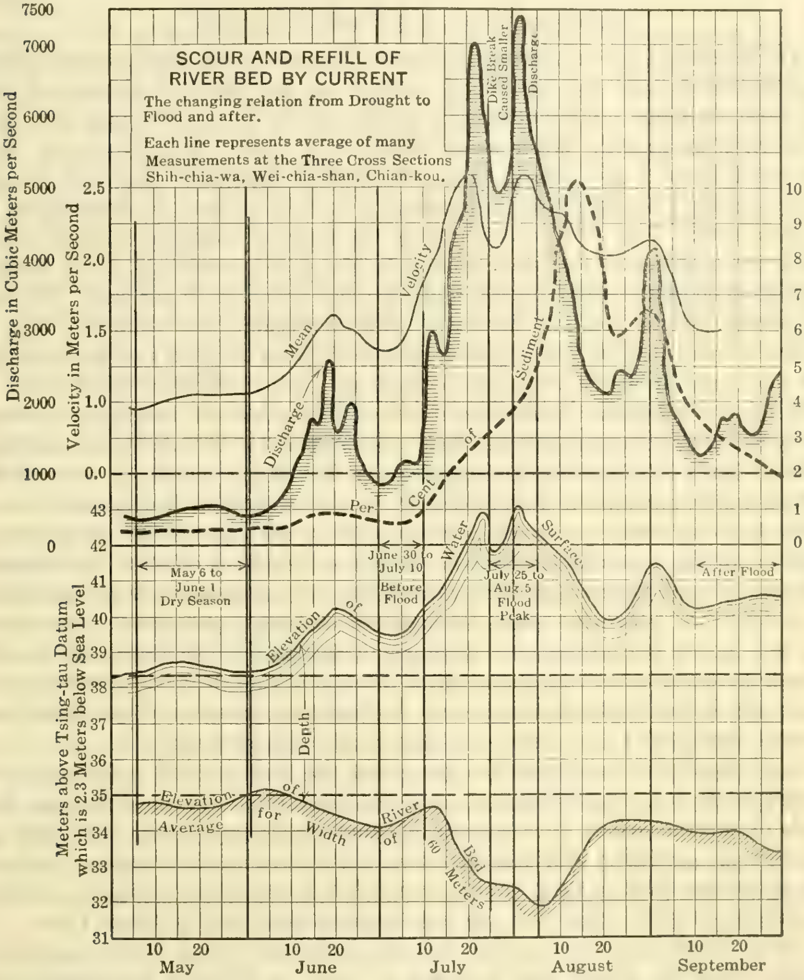


FIG. 18.

A study of this phenomenon, excavation and refill of the river bed as velocity rises and falls, which will be presented later in more detail in the speaker's proposed paper on the hydrography of the Yellow River, points the way to a successful training of this river by compelling it to dig and maintain its own flood channel and to carry its burden of silt to the sea. Many recent hydraulic investigations concur in showing that with increase of depth, velocity increases in a much larger ratio than that given by the Chezy

formula which makes the increase proportional to the one-half power of the depth, whereas the newer formulas make it as the two-thirds or even the three-fourths power. This larger ratio is on the right side to be helpful in the present problem.

Characteristics of Yellow River Silt

The feature of special interest shown in Fig. 18, is the facility with which increased mean velocity was found to pick up an increased burden of silt and carry it along. The normal silt burden at the low-water stage averages about 0.4% by weight. After mean velocities of from 5 to 8 ft. per sec. had continued from 1 to 3 weeks, the silt burdens gradually increased to an average of 6.5% by weight, corresponding to 4.5% by volume as deposited on a compact bank. This 6.5% was found as the mean of eighteen samples taken at six widely different localities from July 31st to September 2d, 1919, during the high flood of the water; at the peak, the load was 9 or 10 per cent. The lag in picking up the full silt burden is very noticeable and indicates that a relatively small part of this is picked up locally from the bed, and that a large part may come from the action of the flood on the loess hills far up stream.

When one calculates these percentages of suspended silt, averaging upward of 5% for 40 days, into an average flood discharge of 150 000 sec-ft., the number of cubic yards of excavation transported per day or per month by the swiftly moving water, amounts to vast quantities in comparison with what man could afford to do by dredges or steam shovels. When one extends the computation to cover all the material transported by this entire flood of 1919, the volume becomes too great for one to believe that the silt movement always has gone on at this rate, year after year, through ten or twenty centuries. The shore line has moved seaward a long distance in the past 2 000 years, but hardly enough to cover such vast quantities. Pumpelly and Von Schermbeck and Visser cite a few localities and records, indicating a progress of the shore line seaward about 100 ft. per year, or about 1 mile in a century.

One should not generalize too far about the total annual volume of silt carried to the sea, until similar observations have been continued through the floods of several years. It is conceivable that somewhere in the loess hills of Shansi some particular cliff may have been cut into at an abnormal rate during this particular flood of 1919, or that something abnormal was going on during the outflow of 1902, which left the vast deposits described by Capt. Tyler.

Many hundreds of samples of this silt from the Yellow River and other streams along the Canal were collected, in 1919, at different flood stages, by subsidence from measured volumes of water and evaporation to dryness. Many other specimens were obtained by cutting out solid blocks from the river margins. The average of many specimens from many localities carefully collected and evaporated to dryness at 240° Fahr., showed for a densely compacted oven-dried cake a weight of 110 lb. per cu. ft. of final size as the maximum, and the ordinary oven-dried specimen weighed about 90 lb. per cu. ft. of original size as cut from the bank. Blocks with their natural water content as taken from a well settled bank along the river, averaged about 120 lb. per cu. ft.

In nearly all samples, the grains of this sand are of such microscopic size that 99% of the whole would go through a cement test sieve having 200 meshes per lin. in. The speaker examined many samples from widely distant localities, under a microscope with a power of 100 diameters. All these samples presented much the appearance of good mortar sand when thus magnified, and by measurement with an eyepiece micrometer, the diameter of nearly all the particles was less than 0.001 in., although a considerable percentage were only about one-tenth of this size. In spite of these extremely small dimensions, very little colloidal or adhesive quality was found, and nearly all the material in suspension in a glass of the turbid river water, 10 in. tall, would settle to the bottom within 15 min., leaving the water above with only a slight opalescence and so clear that fine print could be read through a column several inches in thickness.

This remarkably prompt subsidence has an important practical bearing on training the river so that material excavated in one place may be laid down in another place as desired by giving the silt-charged water a quiet pool in which to lay down its load.

This silt comes from vast deposits of loess in Shansi and other Provinces up stream, the most extensive in the world. In some places, these deposits are said to be more than 1 000 ft. thick. Where the speaker examined the loess hills, or the edge of the plateau, near the Peking-Hankow Railroad Bridge, the loess rises 225 ft. above the river, in steep bluffs, cut deep by small streams during heavy rains. *In situ* loess is a peculiar material and can stand in a bank with a vertical face many feet high; it cuts, smoothly, like cheese, absorbs water readily, and "dissolves" rapidly in a stream.

That sometimes the river carries sediment of much coarser grain, a true sand with grains averaging, say, $\frac{1}{40}$ in. in diameter, is shown by sand dunes outside the banks near the break of 1851, by dunes along the south dike up stream from the break of 1887, by vast fields of drifting sand along the Lung-Hai Railroad, and by drifts high against the eastern city wall of Kai-feng. Apparently, 99% of all the earth seen by the speaker along the Yellow River delta was of the fine-grain variety, of loess origin.

As the speaker cruised down the river in a small boat, he gave much attention to the ever-changing contour of sand-bars and shores and to the varying depths over the sand waves of the bed, frequently prodding the bed with a sounding pole and always finding the bottom yielding, but well defined. The standing waves in the surface of the water in many places gave evidence of sand waves, forming and slowly moving along the river bed. The low-water channel is extremely unstable.

Applications to River Training and Flood Relief

The preceding particulars have been given in some detail because of the possible wide application of the principles of river-bed erosion and re-fill to river training. From superficial observations in several other delta regions in China, the speaker is inclined to believe that a thorough investigation

would reveal similar relations of velocity to scour of bed and its re-fill at several localities where flood channels are needed, and that the methods to be described for training the Yellow River could be made of wide application in China; but before laying out or beginning the construction of extensive works, he would, as a matter of course, insist on surveys, borings, test pits, and a variety of tests of physical qualities at the locality where these methods are to be tried, all made with great care and under competent direction.

One cannot yet be sure that all this silt of the great northeastern delta plain of China presents these characteristics found along the present course of the Yellow River between Shi-Chia-Wa and Lo-kou. Moreover, the speaker has read reports of investigations of silt from beds of smaller streams near Shanghai, which at moderate depths seem to present more of adhesive quality in the river bed and which might resist erosion.

The colloidal qualities of river-bed clays and silts and the causes of remarkable differences in adhesion, plasticity, and colloidal suspension are matters within the profound depths of molecular physics, which are only now beginning to receive the investigation that is merited by their practical importance in engineering operations.

A River-Training Laboratory

At present, there is only one laboratory in the world, as far as the speaker knows, designed for the special study of river-training problems. This is the Fluss-Bau Laboratorium at the Munich Polytechnikum. In 1913, the speaker visited the old and the new laboratories at Munich, and Professor Engels who is in charge, has courteously sent him accounts of some of his recent experiments therein, illustrating the formation of sand-bars and pools and the effect of groynes of various shapes and inclinations on scour and deposit at various velocities. Apparatus of this kind, but on a larger scale, is needed, both in America and in China, for a wide range of experiments on river training, and the speaker has told some of the Chinese statesmen that in skillful hands it might pay dividends of 1 000% per year on its cost, in their river and harbor problems. He would recommend working out the best means of channel training and the best shape of groyne for the Yellow River by trial-and-error methods, conducting experiments on a full-sized structure in the river almost simultaneously with experiments on the laboratory model, and thus seek to develop the precise form of the improvements in a tentative way, step by step; but he would follow the ancient Chinese practice of dike and groyne as far as possible, until it appeared certain that better methods and types had been developed.

A program could readily be planned, under which this careful proving up on designs during the necessary time for surveys need not delay the prompt and rapid carrying out of the sorely needed works of flood protection or flood prevention, along the Yellow River, the Wei or Hai River and the Hwai River, or wherever funds are available.

Protection Against Floods

A Possible Method of River Training

The chief object in the river training now proposed is protection against floods by ultimately forming a thick, flood-proof dike by means of silting up the space between the present inner dike and a new straight dike built to confine the new straight and narrow channel and hold this from meandering, so that it will henceforth flow everywhere between new banks protected against undercutting by spur-dikes, somewhat as shown in Fig. 19.

All things considered, the Chinese have done wonderfully well in their river training by the methods they have followed for hundreds, and perhaps thousands, of years; but it should be possible to make great improvements by means of precise scientific observation and by slow painstaking study in laboratory and field with modern instruments and methods. The facts already observed have convinced the speaker that it is possible to utilize some of these marvellous forces of Nature found in the erosion and transportation of silt, to perform much of the labor of building and maintaining the channels and embankments needed for protection against the outbreak of floods.

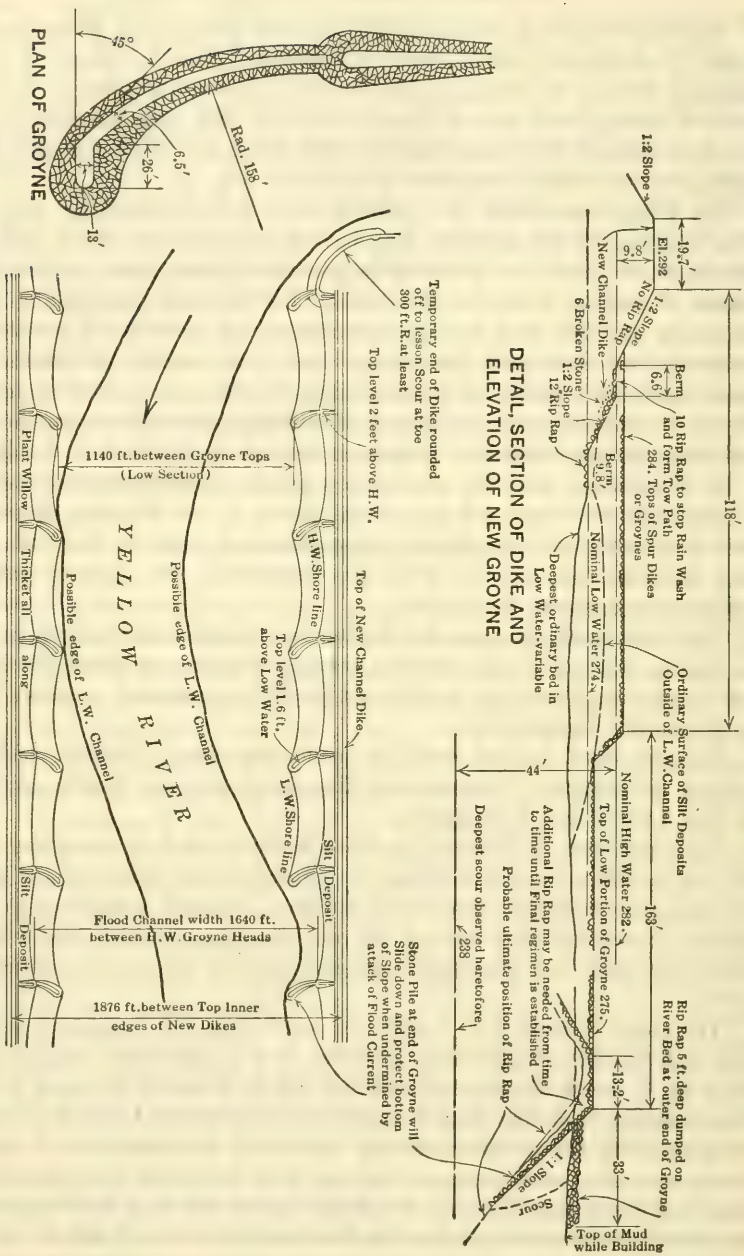
In illustrating what the speaker now has in mind, he desires first to make it plain that the forms and dimensions shown in the following drawings may need to be modified after further observation and study in the field and study in a hydraulic laboratory. With this reservation, the speaker presents the outline design, shown in Fig. 20.

The river would be compelled to flow in straight courses, 5, 10, or 20 miles in length, laid out nearly midway between the present inner dikes, as may best fit existing conditions in different localities, somewhat as shown in Fig. 6 by the parallel straight lines.

The new flood channel would be made only about $\frac{1}{3}$ mile in width at the surface, the centers of the new main dikes being less than $\frac{1}{2}$ mile apart, instead of from 4 to 8 miles, as at present.

Various means in different localities would be used to swing the river into the new straight channel, utilizing the natural erosive power of the current to the greatest practicable extent and building out long spur-dikes to turn the current toward the new channel the opposite dike of which would have been previously built and provided with groynes, lest the current overshoot the mark.

The space of from 2 to 3 miles in width thus left between the old inner dike and the new straight dike, as shown in Fig. 19, would ultimately become silted up to nearly the level of ordinary floods, forming the most fertile kind of agricultural land, like the rich bottom-lands, or intervales of American rivers, but presenting the great superiority of having the admission of flood water always controlled until growing crops had been harvested, by substantial sluiceways and gates built into the new dikes. After the crop had been harvested, the occasional admission of more or less flood water would add to the fertility and aid the maintenance of a deep-seated reserve of moisture in the subsoil. It is obvious that when this broad terrace of earth between the old dike and the new dike has become built up to about the level of ordinary floods, if



ARRANGEMENT OF DIKES AND GROYNES FOR STRAIGHT NARROW CHANNEL
(Subject to revision after observation in Field and experiment in Laboratory)

FIG. 19.

subsequently the inner dike becomes overtopped by an unprecedentedly high flood or undercut by the current under extraordinary conditions, this barrier of elevated ground about 2 miles in width in front of the old dike, would prevent any rapid outrush of water from causing disasters like those of 1887 and 1851, or the countless series of outbreaks that have occurred from time immemorial all along the course of the river through the delta.

The speaker would make each necessary change of direction between these long straight reaches of new channel by means of a relatively short sharp curve of a radius only two or three times the channel width. At present, he attaches little importance to the theory often mentioned in papers on river training that because rivers naturally flow on curves and not on straight lines, therefore, a gently curving course is the best in which to train a river. Nature's chief object in the winding course of rivers seems to be delta building and the distribution of sediments eroded and brought down from the hills; whereas, on the contrary, the object of man in this case and many others is to prevent meandering and bank-cutting and to cause the river to carry its burden of silt in the flood water to the sea in the most direct and certain way possible. It is not believed that the interests of future navigation of the Yellow River would be sacrificed by these straight courses, or that, as a whole, the river dikes would be more difficult to maintain.

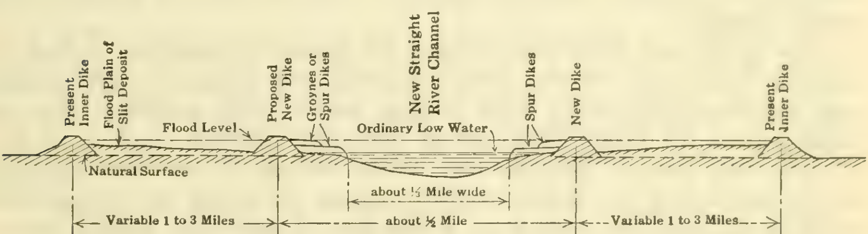


FIG. 20.

Since this paper is primarily on "Flood Problems", the speaker will deal only briefly here on the hydraulic problems, leaving their discussion for another paper already mentioned, that he has in preparation.

Although flood protection is the controlling motive, navigation must not be forgotten. At present the navigation of the Yellow River is confined to a multitude of small boats of about 3 or 4-ft. draft, 10 ft. wide, and about 40 to 50 ft. long. The shoals are many and capricious. It seems certain that the new, confined and deepened channel would bring great improvement over present conditions.

As to possible troubles from hills and hollows, or shoals and pools, in the river bottom, caused by the alternate obstruction at the groynes and the enlargement and eddying below the groynes, the speaker was encouraged to believe that a satisfactory condition could be worked out, by his observations of the currents, shoals, and eddies at the old Chinese groynes along this river, during his cruise between the railway bridges in December, 1919. Nevertheless, he would propose a careful study of the best spacing for groynes

by laboratory models, before building many structures in the field, and would take long and careful counsel from the most experienced Chinese conservancy superintendents, and would carefully study the sand waves in the bed, of which he noted many examples as he cruised down the river.

The long continued and almost general use of the spur-dike by the Chinese for turning an impinging current away from a dike built of soft, easily eroded earth naturally calls attention to that type of construction, as having been proved by centuries of experience to be well adapted for meeting local conditions. Moreover, it takes little arithmetic to show that a smaller quantity of stone rip-rap will be required for protecting a mile of river bank when this is carefully and scientifically disposed in spur-dikes than if placed in a continuous line of rip-rap parallel with the shore. Also, any sudden freak of the river in threatening the dikes at a particular point can be most quickly warded off, with a smaller quantity of stone and by fewer men, when the material is dumped off the end of a narrow spur-dike.

In brief, although the speaker has confidence in the general method herein proposed, he would at first build only 2 or 3 miles of new channel with the new shape of dike and groyne, and study its behavior and expect to improve the details. Meanwhile, he would seek maximum economy through painstaking observation, experiment, and the counsel of others, and then proceed with greater lengths.

One of the most important problems for present consideration is that of devising the cheapest effective means of placing and holding the river in the new pre-determined course while making use of cheap materials near at hand. Along the Yellow River and at convenient intervals on many of the Chinese delta streams, limestone hills project through the vast deep deposits of silt, from which any desired quantity of stone for rip-rap can be quarried. In some localities, the river flows at the foot of these hills, making transportation by native boats economical; this fact suggests the use of rip-rap much as the Chinese have used it in their spur-dikes from time immemorial.

It is quite within the range of probability that the straightening, shortening, and deepening caused by the new system of a straight and narrow way would gradually cut down the bed of the river to an elevation materially below the plain, so that the great danger which comes from silt deposits raising the bed and from the super-elevation of the normal surface above the general level of the country outside the outer dike would gradually become lessened. As to the possibility of trouble from interference with Nature's process of spreading silt from the Shansi hills over the delta surface, through arresting the occasional change of the river's course, or through the more rapid extension of coast line or the shoaling of the Yellow Sea, these possibilities are about as remote in the future as the Cro-Magnon civilization is remote in the past, and present generations need not worry.

Brushwood Retards.—There are many places where the cheapest and quickest means of diverting or of holding the Yellow River to a new channel would be by checking the current and causing sand-bars to form by means of a floating raft of bushy trees, if trees could be had. This part of China is

practically treeless, and each bit of wood is so treasured by the Chinese peasant that it might require an army of soldiers to protect a quick-growing forest of cottonwoods or the like. Nevertheless, taking a long view of China's great problems of flood protection and river regulation, the Government might well consider immediately setting apart and planting suitable trees for this purpose. Trees of serviceable size for these purposes could be grown long before China will have its river-protection works one-tenth finished.

Training the Yang-tze

This river greatly needs training for preventing the destruction of valuable fertile shores by erosion and caving; also, for purposes of navigation in increase of depth, and a more permanent channel. For the Yang-tze River, with its far greater volume and depth, naturally there would be devised a different arrangement from that found to be most economical on the Yellow River. Along the Yellow River, thus far, no evidence has been found of deep holes being dug by the swirl of the current, to a depth of more than 30 or 40 ft. below the low-water surface, although possibly this may occur; but along the Yang-tze River in its 600-mile course from the great City of Hankow ("the St. Louis of China") to the sea, the navigation charts show many submerged gullies more than 100 ft. and some even 125 ft. in depth. Even when a current of this great depth attacks a protected shore line, defense would seem to be possible by some such special means as trees with bushy tops, sunk by heavy stones tied to their stems and laid over one another like shingles. The quick subsidence of the Chinese river silt favors the rapid building up of great deposits in eddies or where the current is checked by such material as bushy tree tops.

In general, the channel will seek the line of least resistance, and in this delta region there appears to be an almost unlimited depth of easily eroded silt which can be cut at the bottom in mid-channel to any needed depth on any desired location; and it is of great importance that in the beginning the new straightened and improved channel be laid out on the best possible lines.

Apparatus and Methods.—The cheapness with which this soft earth can be excavated, moved, and put in place by native labor, also must be considered in planning great works for flood relief. Methods that would be followed in America with its high-priced labor and convenient great machine shops would be out of place in China where earth can be excavated on a large scale and moved by men with native shovels and baskets at a cost of less than 10 cents per cu. yd., and where a working force of 10 000 willing and industrious laborers could be quickly assembled along any given stretch of river, most of whom would be greatly benefited by the distribution of money. A drag-line scraper with a long boom would be useful here and there for work below the water level, but, in general, funds expended for manual labor would do far more good to humanity, distributed among the farmers for miles around, than if put into expensive dredges, steam shovels, and construction-railway material manufactured in foreign lands.

Agricultural Improvements

Although "Flood Problems" is the title of this paper, and the chief object of this work proposed along the Yellow River would be the safe-guarding of the many millions of population on farms and in small cities within a few hundred miles north and south of its course, from any such outbreak of flood as that of 1887 or of 1851, there would be an important incidental benefit from converting the strip of land, from 4 to 8 miles in width, between the inner dikes from its present condition of partial and hazardous use to one of security, fertility, and maximum use, making it comparable with the Upper Valley of the Nile above Cairo. On this narrow strip, vast quantities of food could be grown with certainty, in years of greatest drought, in the midst of a land where fearful famines sometimes occur from the shortage of rain. Some of the worst famine districts, in which the American Red Cross and other humane agencies expended more than $1 000 000 in 1921, are close at hand to the strip of "river bottom" that could thus be made sure to yield two bountiful harvests each year, regardless of the general shortage of rainfall.

Regarding the agricultural development of the strip between the dikes, this would be subdivided into alternating tracts, the progressive development of which would be changed from time to time. For example, at first, there might be certain large areas outside the inner dike, set apart by low dikes, to be irrigated by gravity flow through carefully constructed conduits. The present super-elevation of the surface of the river above the level of this surrounding country could thus be made a blessing instead of a danger, since this super-elevation would provide the fall for distributing the irrigation water. To just what extent the abstraction of water for this purpose would be permissible remains for future consideration.

Another means of shaping the flood-relief work for aiding agriculture would be by establishing impounding reservoirs within cross-dikes between the old inner dike and the proposed new dike, each of which reservoirs might present several square miles of surface 10 or 15 ft. in depth of water until shoaled by silting.

These impounding reservoirs might be located on alternate sections and the reservoir section used for irrigating the section from which water was excluded by the new dike and after, perhaps, 10, 20, or 40 years, when this reservoir had become shoaled by silt, it could then be treated as agricultural and irrigated from the river by pumps of many kinds, some perhaps driven by wind-mills.

The Huai River Flood Problems

The flood region of the Huai River is shown in Fig. 3 and Fig. 21. The American Red Cross is said to have expended about $400 000* in 1911 in food, supplies, and other means of relief in the famine which resulted from floods along the Lower Huai River, and followed this by a practical effort to help prevent such disasters in the future by sending an engineering commission composed of members of the Society to China to advise with the Chinese on means of improvement in this Huai River District.

* See Reinsch, "An American Diplomat in China", pp. 70–80.

Probably no place in the world more urgently needs improvement by works on a large scale. As has been stated previously, Mr. Chang Chien, scholar, statesman, and foremost Chinese industrial leader, moved by a desire to be of service to his native Province, had developed a school of conservancy engineers who had been collecting data and making surveys for several years prior to the coming of the engineering commission sent by the American Red Cross. The Red Cross engineers made a careful study of the data already collected by the Chinese, and under difficult conditions, made a somewhat hurried personal reconnaissance of the region. In the course of a few months, the Board submitted its report with recommendations for a plan of drainage channels and reclamation works, estimated to cost about \$30 000 000; but no financing followed.

The problem appears to have been too large and too difficult for satisfactory solution with the data, the time, and the means then at the command of the Board; and its plan of works has not been approved by the Chinese, who have continued their surveys more or less actively under Chinese leadership. A year and a half ago, His Excellency, Chang Chien, presented a tentative report for a scheme of relief radically different from that proposed by the Red Cross Board, calling for an expenditure, first and last, of about \$45 000 000, at the present rate of exchange, suggesting that the work be done largely by the soldiers of the needlessly large Chinese Army which had been called into existence during the World War, and could not well be disbanded and turned loose without employment or means of support. Within the past year (1921), additional surveys have been going on and a young American engineer, E. W. Lane, Assoc. M. Am. Soc. C. E., recently of the Miami Conservancy and of the Morgan Engineering Companies, has been called to China to assist Mr. Chang Chien's organization on canal improvement and other hydraulic problems in Kiang-su Province.

When studied in a broad and thorough way, this problem of the Huai River flood relief is extremely complicated, combining river training, flood-detention reservoirs, irrigation supply, the exclusion of sea water from flowing back in the channels in time of drought, the improvement and modernizing of about 100 miles of the Grand Canal, as well as the reclamation for agriculture of vast areas of shallow lake beds. As previously stated, the finding of a practical solution intimately affects the lives and prosperity of 2 000 000 inhabitants in one of the most fertile regions of the world, which might be far more densely populated if only the present terrible succession of floods could be prevented.

Until about 728 years ago, affairs appear to have gone on comfortably in this district, as affairs go in China. Then, the Yellow River broke away from its older channel and usurped the bed of the Huai River and by raising its bed with deposits of silt, and thus finally completely excluding the Huai River from its ancient bed, forced the enormous Huai flood volume, sometimes more than 250 000 sec-ft., to find new outlets to the sea, partly through scant sluice-ways in existing dikes and partly by way of the Grand Canal to the Yang-tze.

The Huai drainage basin comprises 52 000 sq. miles, on which sometimes 10 or 12 in. of rain falls in a single storm. The crude maps available indicate that more than three-quarters of the catchment area is hilly or mountainous, and that less than one-quarter is flat, low-lying delta bordering on the sea.

A few centuries prior to the forcing of the Huai River from its ancient bed to find new outlets, there had been built across the delta, a few miles back from the sea, the great Maritime Dike, 100 miles or more in length, for protection against tidal waves and pirates, and the outlets for local streams provided through this great dike were inadequate for the discharge of the Huai floods of 250 000 sec-ft., or more. Thus, whenever a heavy flood came down the Huai River, more or less of 10 000 sq. miles of delta farms became submerged, while the water slowly drained off through the small seaward channels and down the ancient channel of the Grand Canal into the Yang-tze River. A large part of the water did not drain off, but became impounded in vast shallow lakes aggregating in area about 1 575 sq. miles.

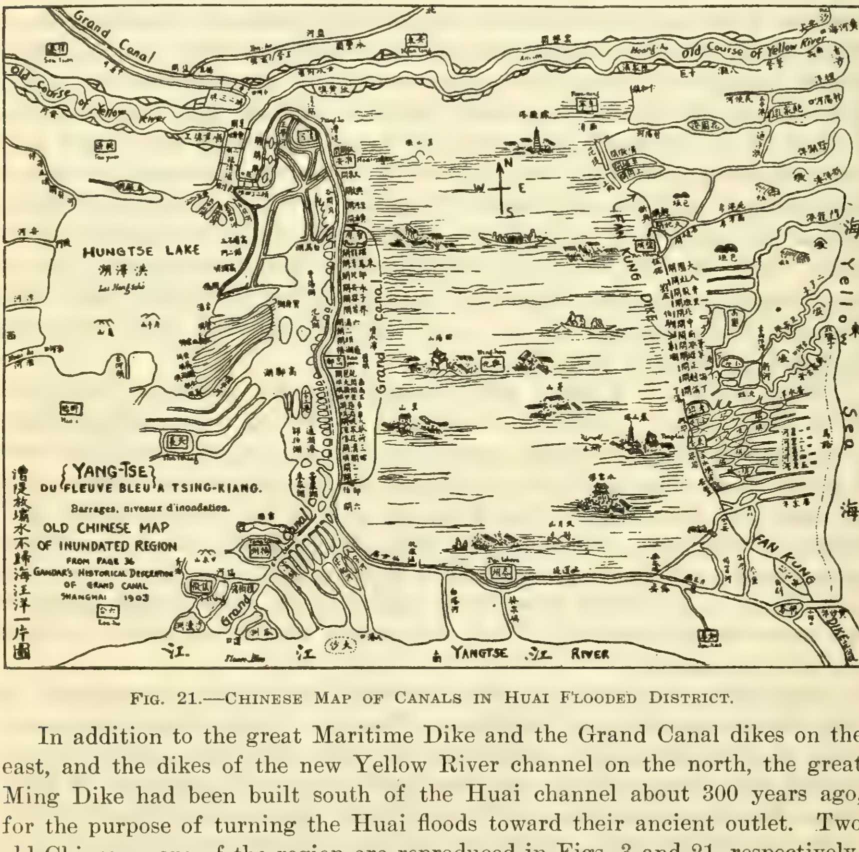


FIG. 21.—CHINESE MAP OF CANALS IN HUAI FLOODED DISTRICT.

In addition to the great Maritime Dike and the Grand Canal dikes on the east, and the dikes of the new Yellow River channel on the north, the great Ming Dike had been built south of the Huai channel about 300 years ago, for the purpose of turning the Huai floods toward their ancient outlet. Two old Chinese maps of the region are reproduced in Figs. 3 and 21, respectively, the first showing the district flooded and the second some of the 3 200 miles of canals and watercourses, which are at various levels and serve the three

purposes of transportation, drainage, and irrigation, but which fail to provide sufficient sluiceways and main outlets to give escape of floods to the sea.

An excellent history of the Grand Canal in Kiang-su Province, with a most interesting story of the successive disasters, was published by a French priest, Father Gandar, at Sicawei, near Shanghai, in 1903. This history was derived from ancient Chinese sources and begins with a terrible deluge 2 357 years before the Christian era. Father Gandar quotes statements from Confucius about the earliest section of the Grand Canal, which was built in this district 486 B. C. For the past 500 years, he tells a story of prolonged suffering from floods, and of Chinese courage, industry, and perseverance in fighting back these floods, which has no parallel in history. Coming down to recent times, he states that within the 50 years of the Kun Yan Period, from 1746 to 1796, there were 16 years of flood, and in the 37 years, from 1844 to 1881, he tabulates the height of thirteen bad floods. After the Yellow River again migrated northward, in 1851, the floods became more rare, but the river, during its 530 years' usurpation of the old Huai Channel, had raised its bed and also had been confined by high dikes, so that, although this ancient channel was now empty, the Huai River could not now climb back into it or use it.

The speaker was invited to study the flood problems of this region, but was unable to prolong his stay in China for that purpose, and purely as a good-will offering to the friendly Chinese, he has since spent much time studying the data collected by their engineers, and some months ago ventured to submit for consideration an entirely new plan of relief, which should take advantage of the discoveries about the erosion of delta silt by the Yellow River, previously described, and which also should give to the Huai floods the shortest and straightest course possible to the sea.

The speaker also suggested that if test pits and borings should prove that the soil in this part of the delta was as easily eroded as that along the present course of the Yellow River, the erosive power of the flood itself might be trained to do a large part of the work of excavation and thus reduce the cost of the great flood channel needed to a sum within the possibilities of financing.*

Under present conditions of finance in the world in general and in China in particular, it seemed hopeless to raise the $90 000 000 Mex. required to carry out the project of relief developed by the Chinese engineers. Moreover, the speaker was led to believe, through a study of all the data that he had been able to obtain, that by means of a different plan a vastly greater area of shallow lake beds could be reclaimed for agriculture than had been proposed in either the Red Cross report or the later Chang Chien report of 1919.

Tentative estimates on rather bold and broad lines, from limited data, indicated that the value of the land that could be reclaimed would become sufficient to reimburse the entire cost of the necessary drainage channel and all the other flood-protection works required in this large district.

* A special paper on these Kiang-su flood problems is in preparation by the speaker, and has already been submitted in a first draft, subject to revision, to several of his American and Chinese engineering friends for their counsel and constructive criticism.


MAP SHOWING
LOCATION OF
PROPOSED
NEW CHANNEL
OF THE
HWAI RIVER
All Contours are in Meters
above Mean Sea Level
118°
119°
120°
121°
35°
34°
33°
32°
N
Tai-chwang
Pelao
CENTRAL
R.
SHANTUNG
KIANGSU
Hai-chow Bay
YELLOW SEA
NORTH DIKE OF ABANDONED
CHANNEL OF YELLOW RIVER
SOUTH
DIKE
Yao-wan
Yi R.
Loma Lake
Chin-yi Lake
Hsian-wei R.
Shu-yang
PROPOSED FLOOD CHANNEL
Su-chien
Liu-Lao-Kien
N. Liu tang R.
S. Liu tang R.
Kwan R.
YEN
CANAL
Tatung Kow
Lein-shui
Tai-kuan
Yang-chwang
Antung
Old Yellow R.
Hwai-yin
Hwai-an
Hwai R.
Hung-tze Lake
THE GREAT DIKE OF HUNG-TZE LAKE
KIANGSU
ANHWEI
Many miles of minor Canals in this Region are not shown
INNER
GRAND CANAL
Peh-ma Lake
Pao-yin Lake
Pao-yin
Hsia-yang Lake
Hsia-yang R.
Hsin-yang R.
FANKUNG
Tou-lung R.
Cha-shu Lake
Kao-yu Lake
Kao-yu
DIKE
TIENTSIN - PUKOW R. R.
Pukow
Yang-chow
Kwa-chow
Hsiennu Miao
Sin-kiang-yin
Nanking
Chin-kiang
Tanyang
Kintan
Chang-chow
Chang Tan Lake
Ko Lake
Liyang
GRAND
SHANGHAI
CANAL
Wu-hish
NANKING
Yangtze R.
Tung-chow
Ihing
Tai Lake
Soo-chow
Kun-shan
Tai-tsang
Kiating
TSUNG MING IS.
Poa-shan
Wu-sung
Shanghai
KIANGSU
CHEKIANG

FIG. 22.

The method worked out by the speaker is shown in Figs. 22 and 23, which present, respectively, a map of the district showing the location of the proposed new channel and a cross-section illustrating a possible method of constructing the new flood channel. This new straight channel would serve both navigation and irrigation and would also carry the discharge of the Huai River under normal conditions.

It was suggested that if borings and test pits showed favorable ground, all that need be excavated was one, or preferably two, deep, narrow channels inside the edges of the future main channel, which preliminary channels, providing barely sufficient earth with which to build the new dikes, should be cut so deep (about 30 ft.), that under the existing slope and brief yearly conditions a scouring velocity of from 5 to 8 ft. per sec. would be produced, which velocity it was believed would rapidly cut away and carry off, as long as the flood flow lasted, the silty material between these two preliminary ditches. The floods of several years were expected to complete the work gradually, aided here and there, and from time to time, by special training dikes and groynes and by men and baskets or by dragline excavation where necessary. The hydraulic estimates were worked out with considerable detail. The determination of the shape and depth of the preliminary channels for the production of maximum scour is a somewhat intricate problem of itself, but this paper is not the place for the presentation of those special problems, and this whole Kiang-su problem requires more study both in the field and in the laboratory.

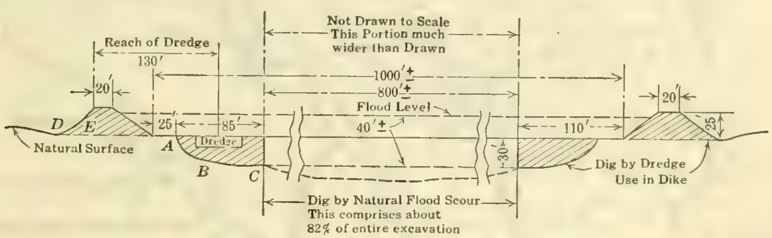
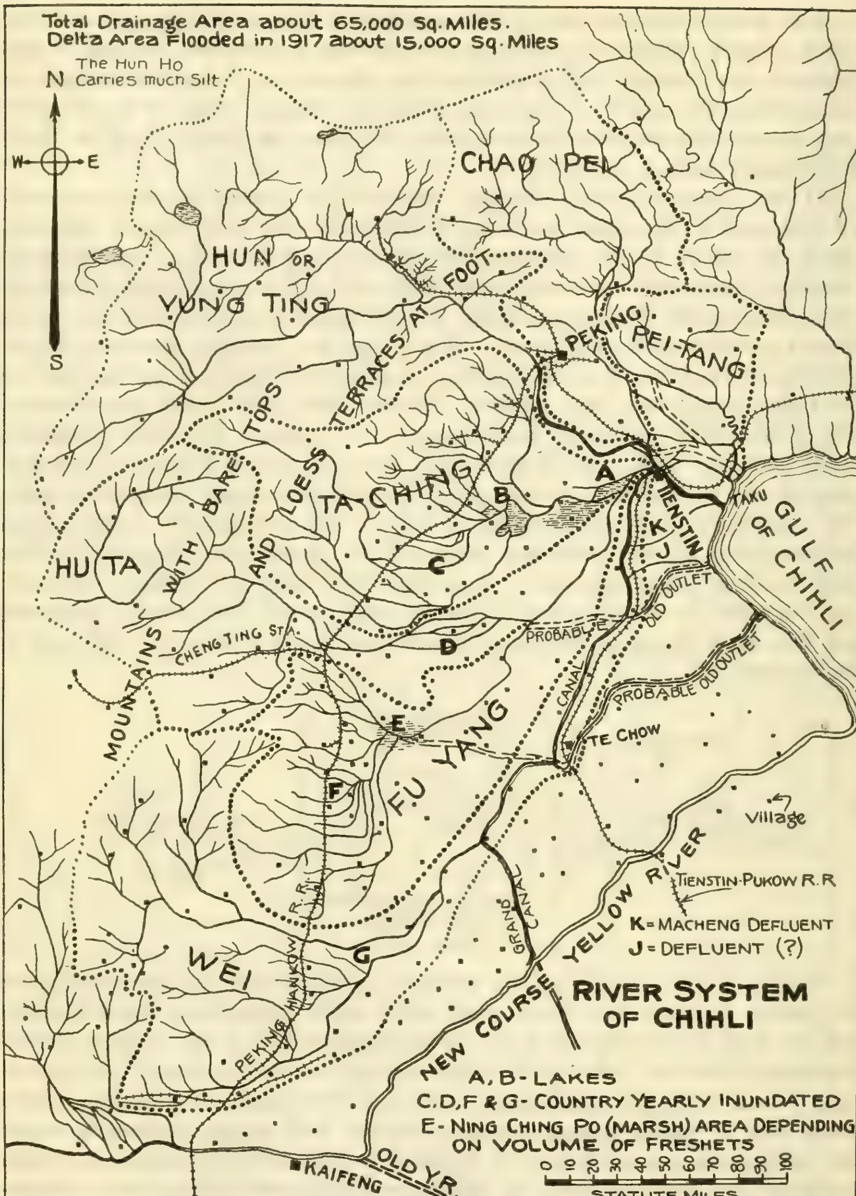


Fig. 23.

Such a project would not be definitely recommended by the speaker, or its precise location laid down, until after much preliminary investigation, but the hope of accomplishing the much-needed relief to the district and of recovering 1 000 sq. miles of the most fertile land in the world for agriculture, which now lies submerged under shallow lakes, in a region where every acre is badly needed, which reclaimed land might ultimately repay the entire cost, seems worthy of extended consideration in comparison with the plan proposed tentatively by the Chinese engineers calling for an expenditure of $90 000 000 Mex. The speaker has no other interest in this project than that of being helpful and the attraction of a fascinating engineering problem.

The straight course is proposed to be designed with dikes protected in some localities by groynes, somewhat as shown in Fig. 20, or on other locations, as *A-G*, *A*-1, *M-N*, or wherever natural conditions most favored construction. In some localities, instead of the stone-faced spur-dike shown in Fig. 20, it



Hun Ho has heavy silt burden. Deposit of which has elevated bed in Lower River and forced it into Ching Ho-
Ching Ho has large storage.

Hun, Chin and Si each supposed diverted from original outlet to aid Navigation via Grand Canal.

Name of River	Area of Water shed in Sq. Kilom.
Chao Pai Ho	25,500
Yung Ting Ho	54,800
Ta Ching Ho	32,200
Hu Tuo Ho	30,700
Fu Yang Ho	30,000
Wei Ho	43,200
Pei Tang Ho	14,000
Total	230,400

FIG. 24.

might be better to use groynes of submerged concrete sheet-piling, reinforced with large split bamboo, instead of with steel rods. It would be pleasing to the builder to obtain his reinforcement from quick-growing plantations alongside the work.

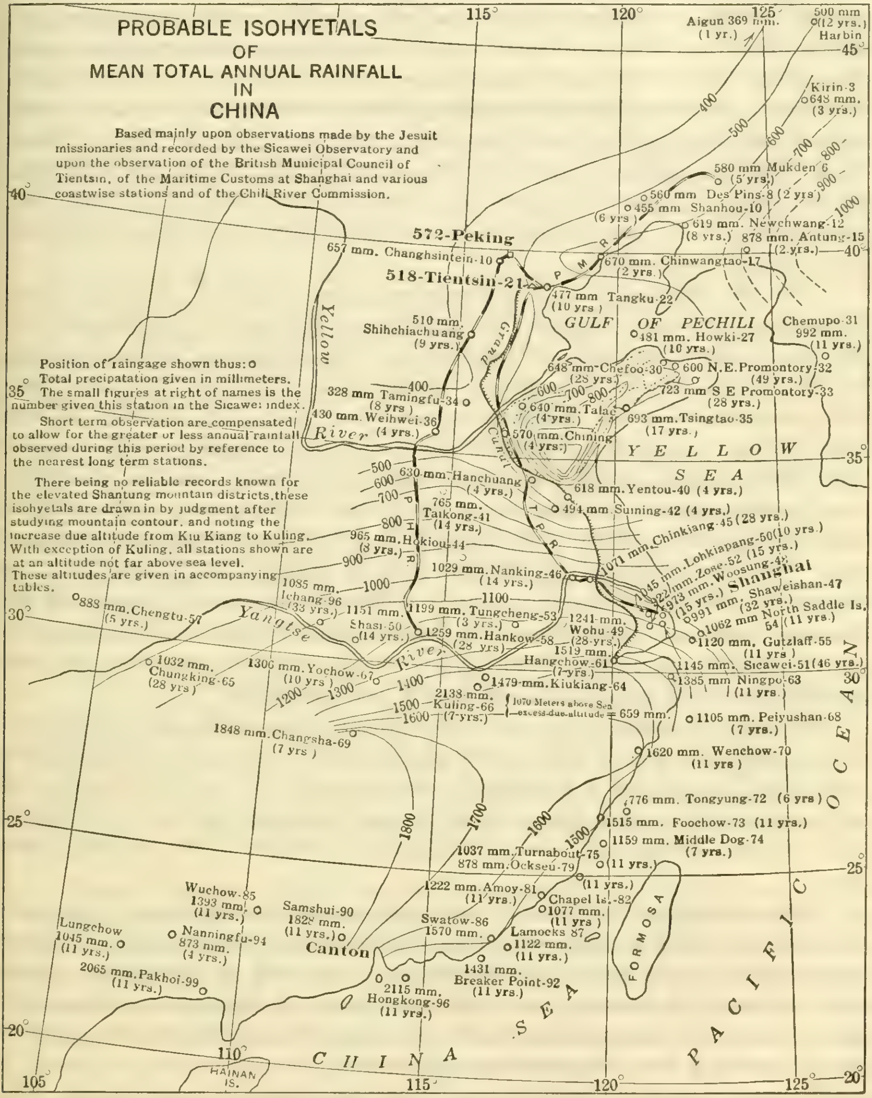


FIG. 25.

The Chihli Flood Problems

A map of this catchment area is given in Fig. 24. The terrible results of these floods of July, August, and September, 1917, have already been briefly described. Most of the delta of 12 000 sq. miles was inundated, bring-

ing great suffering to more than 5 000 000 people and a property loss of more than $50 000 000. In general, this was said to be the worst flood in 140 years.

The conditions of soil, slope, and drainage, in this delta are substantially the same as for the deltas of the main Yellow River and that of the Huai, for all are of common origin—loess brought from the hills by floods and deposited in vast, nearly level deltas—and all have the present rivers diked in; but the flood in Chihli is of local origin, from a water-shed not distant more than about 250 miles from the convergence of the five rivers shown in Fig. 24. Therefore, the Hun River floods are quicker, briefer, and relatively more violent, considering the small water-shed, than those of the Yellow River. This Chihli water-shed, as shown by the isohyetal map, Fig. 25, lies where the annual depth of rainfall averages only about one-half that of the Huai, but, nevertheless, it can have precipitation in a single storm as much as that of the great Miami Valley flood.

From the manuscript of a preliminary report by Mr. H. Van der Veen, Consulting Hydraulic Engineer to the Chinese Ministry of the Interior, the following interesting facts are transcribed. The rainfall at Shir-kia-chuang, on the railroad at the western edge of the delta plain, near the foot of the hills, as recorded by the Administration of the Tcheng Tai Railway, showed about 40 in. of rainfall in the three months of July, August, and September. This three months' rainfall is about double the average total for the whole year in that region. Of this, about 18 in. fell in July, and on the 26th of that month, 10.4 in. fell in one day, following ten days of almost continuous rain. This was followed by 10.7 in. more in August, and nearly 9 in. in September, thus saturating the ground. Although rain-gauges throughout the drainage basin were lacking, the fact that widespread floods were simultaneous on the several converging rivers shown in Fig. 24, indicates that this one gauging presented something more than a local condition.

The best information now available indicates that, although a large part of the catchment area in the lower slopes of these Chihli hills is covered with loess earth, which has a remarkably great capacity for quick absorption of ordinary rains, the upper parts of the hills and mountains are steep and mostly bare of loess, having been almost completely deforested a few hundred years ago.

The conformation of foot-hills and plain in this drainage area is nowhere favorable to building large detention reservoirs, and no detention of water precipitated beyond the natural absorption of the soil, is practicable, except such as might be brought about by many years of reforesting. Immediate protection would seem mainly a matter of dikes and carefully planned channels and of building the farmhouses on mounds.

A partial protection by detention in ordinary floods is given by the wide distance between the existing dikes and by the extremely crooked courses of the rivers as they meander between the dikes, all of which tends to delay the progress of the flood and to give a moderate volume of storage space when the bank-full stage is exceeded. Unequal delay on different streams tends to prevent their flood peaks from coinciding and, perhaps, it is in part this

excess of channel length and excess of width between dikes in the upper part of the delta that has made the narrow, single channel within the City of Tientsin tolerable for so many years. The maximum discharge capacity of this channel at the time of the 1917 flood is estimated to have been only from 35 000 to 50 000 sec-ft., whereas the estimated discharge in the Hun River alone was upward of 200 000 sec-ft. The widespread suffering caused by this flood was almost beyond description.

The Chihli River Improvement Commission

All this led to immediate action by the Chinese Government and the appointment of the best hydraulic engineering talent available in China on an organization which developed into the Chihli River Improvement Commission. This Commission is still at work with a corps of Chinese engineers, under the advice of an English chief engineer of much experience in India, who has, for his principal assistants, two members of the Society.

The message from President Feng-Quo-Chang to the inaugural meeting of the Commission read like a verse from an ancient poem. It was brief and to the point and worthy of a land great in classic literature:

"The great flood has caused my people miseries,
The down rush of mad water has demolished embankments and dikes,
In haste let engineers be consulted with conservancy measures,
For in this way the nation as well as the government will be benefited.
The Han Emperor in person led the people to work on the damaged rivers
And in return for his zeal, Heaven blessed his reign with prosperity.
Let the Commissioner vie with the illustrious Emperor in the merits he achieved,
And secure for modern China prosperity as great."

Maps, river gaugings, and many data have been secured for the rivers of Chihli Province, particularly for those having their outlets past the great commercial city of Tientsin. So far as the speaker has learned no definite locations or dimensions for flood-relief channels have yet been decided on, except a short cut across a bend through Tientsin, already completed, and some work in extending and deepening the defluent channel of the Ma-cheng Canal.

Several tentative suggestions have been made from time to time, and some surveying has been done for several defluent channels, by which flood water could be deflected from the Wei and other rivers down ancient shallow drainage courses, across the delta to the sea, some of which may mark the site of prehistoric channels of the Yellow River, and are shown in Fig. 5. There seemed to be a popular demand for such flood-diversion channels, so strong that it was difficult for the Commission to resist it.

The speaker inspected the site of the offtakes for some of these proposed defluents, which have been utilized to some extent in the past, but now are clogged with silt, and was led to believe that this method of relief by defluent channels as first proposed would not be permanently successful, because of certain fundamental principles of hydraulics, which lessen the power of a stream when subdivided to cut its way, or to carry its burden of silt, as effi-

ciently as when consolidated in a single channel. In fact, such subdivision is reversing the process of Nature, which unites streams as they proceed. Incidentally, the speaker may remark that he saw an illustration of what is likely to happen, down stream from any defluent from a silt-laden river, in the present conditions below the Ma-cheng Defluent, on the Wei River, where the defluent channel, or so-called "canal", had become so filled with silt as to be useless for navigation during the dry season, and where the main river, below the point of abstraction of water, immediately becomes narrowed or shoaled by dropping a part of its burden of silt. The vast burden of loess silt brought down by the floods greatly complicates the problem.

To a statesman or to a business man who has not carefully studied these matters of flood and silt transportation in the light of hydraulic science, it might seem that the obvious way of preventing inundations at the populous and important city of Tientsin would be to provide a channel for diverting a large part of the water before it reached Tientsin and retain meanwhile the present channels into and out from the city to the sea, but the great and uncommon burden of silt in time of flood has to be reckoned with. The speaker is inclined to believe that the best permanent relief would be found by concentrating the entire flow into the straightest and narrowest channel computed to be able to carry the maximum flood volume.

The best location for this channel is another question. Perhaps, this single river channel could be safely made narrow and diked to dig itself deep and flow through the midst of this city, or it could be deflected to one side and a loop canal built from this flood channel through the city for the needs of navigation.

It is no small problem to determine how best to improve or to preserve during flood and drought the much needed, deep ship channel from Tientsin to the sea. It has been said that 2 000 years or more ago, Tientsin stood near the edge of the sea, but, because of the delta growth, it is now twenty miles distant from the sea, with a bad bar at the river's outlet. The tendency of salt water when mixed with fresh water to cause the latter to precipitate its burden of silt seems to be in evidence at the mouth of nearly all these great Chinese rivers.

Flood Waves

This type of flood problem appears to be presented in the slopes of the Shantung Mountains leading out on to the delta plain. In the course of the Grand Canal surveys, evidence was found of almost incredibly large flood volumes flowing for brief periods from relatively small catchment areas, for example, on the Wen River, which flows from the northwestern denuded slopes of the Shantung Mountains. Careful explorations were made and levels were run over a long series of flood marks along the river, which are undoubtedly authentic. Their height and slope when combined with measurements of the cross-section of the river showed, by computations from the Kutter formula, a flood discharge at the maximum of about 330 000 cu. ft. per sec. from about 3 200 sq. miles, which is larger than the greatest flow measured at the peak of the greatest flood in the neighboring Yellow River from about one hundred times this Wen River drainage area, during the past

ten years, but this Yellow River flood continues for about two months, while that of the Wen, the mountain torrent flood, continues great only a few hours.

In 1914 the Red Cross engineers happened to have an opportunity to gauge a flood flow in the Yi River of probably 140 000 sec-ft., from an area of about 4 750 sq. miles, and there are other evidences of extremely violent brief floods from the westerly slopes of the Shantung hills.

The speaker is inclined to explain the extreme height of these floods, as well as their brief duration, by conditions not unlike those found in some parts of the Western United States which cause an extremely sudden flood, commonly attributed to a "cloudburst". In these cases, an almost instantaneous rise of perhaps 10 or 15 ft. occurs in the stream surface within as many minutes, often with disastrous effects to cattle or teams that happen to be within its reach.

A possible explanation is that under the well-known hydraulic law by which the velocity of flow in a channel increases with the depth, so that four times the depth gives double the velocity, according to its one-half power of the depth, as given by different authorities, the water in the rear, having advantage of the increased depth, travels faster and overtakes and piles on top of the earlier run-off, thus creating the great height of the advance wave. Recent authorities made the velocity increase in a higher ratio to the depth, some as the two-thirds power, some as the three-fourths power, instead of as by the time-honored Chezy formula.

This particular flood phenomenon is well worthy of more observation and of more careful scientific study than it has yet received.

FLOOD CONTROL OF THE MISSISSIPPI RIVER

By J. A. Ockerson,* Past-President, Am. Soc. C. E.

In view of the fact that, in recent years, devastating floods on relatively small streams present intricate problems in local flood control, the work of controlling the floods of the Lower Mississippi River looms as a gigantic undertaking. The Mississippi drainage basin covers an area of 1 240 050 sq. miles and the eastern extremity extends into Western New York about south of Buffalo, the western extremity, into Montana, west of Butte; the northern, into Western Canada, 70 miles north of the boundary line; and the southern extremity, at the Gulf of Mexico. Besides all or parts of thirty States, this drainage basin includes 20 000 sq. miles in Canada. It covers 1 822 miles in longitude and 1 449 miles in latitude, or 41% of the United States proper.

This great basin is divided into several tributary basins, as shown in Table 3, in which is also tabulated the mean annual rainfall in each, for a period of 25 years, as published in *Bulletin E* of the U. S. Weather Bureau for 1897.

TABLE 3.

Name of basin.	Square miles.	Percentage of whole.	Average annual rainfall, in inches.
Ohio	201 700	16	44.2
Upper Mississippi	165 900	13	31.9
Missouri	527 150	43	19.4
Arkansas	186 300	15	29.6
Red	90 000	7	39.1
Central	69 000	6	51.4
Total	1 240 000	100	29.8

It was inevitable that the gathering of water from this vast area would produce tremendous floods, particularly from the mouth of the Ohio down to the Gulf, and the people, who were attempting to reclaim the fertile basins, were unable to cope with them, although they taxed their resources to the limit. This water poured down on the 29 790 sq. miles of the delta basins of the Lower Mississippi and appeals for Federal aid were long ignored, on the theory that the protection of private property was not a function of the Federal Government.

It remained for an ex-slave, in an appeal to Congress, to call attention to the fact that the people only wanted protection from the floods forced on them from other States. "Let them take care of their own water and we will take care of ours," said he. This caused a change of view and, in time, it came to be considered as reasonable for the country as a whole to render aid. Aside from that, the reclamation of this great area of the most fertile

* Cons. Engr.; Member, Mississippi River Comm., St. Louis, Mo.

part of the United States, making it habitable both as to health and exceptional crop production, was and is a good investment.

The people in the delta basin below the Ohio have expended $111 679 618 in the construction of levees since 1882, and the Federal Government has expended $47 583 368 up to December 31st, 1920. Large sums were spent by States and local interests prior to 1882, but the amount has never been satisfactorily determined. Under the present Flood Control Act, the local levee districts are required to contribute at least one-half as much as the Federal Government allots to levee construction. From 1882, when Federal allotments began, to the passage of the Flood Control Act in 1917, the local districts devoted twice as much, or even more, to levee construction than the Federal Government, and even to-day the States and levee boards spend annually, on their own initiative, much more than the contributions required by law.

The Mississippi River Commission was created by Act of Congress in 1879 and was charged with developing and executing plans for the improvement of the Mississippi River, to "correct, permanently locate, and deepen the channel and protect the banks of the Mississippi River, improve and give safety and ease to the navigation thereof; prevent destructive floods; promote and facilitate commerce, trade, and the postal service." It is a most comprehensive law and reflects great credit on the vision of its framers.

Immediately after its organization, the Commission began the study of the physics of the problems assigned to it and exhaustive surveys, topographical, hydrographical, and hydrometrical, were undertaken. River slopes, velocities, and discharges at various stages and localities, were measured. The character of the bed and the banks was determined, the causes of bank erosion and bar building were studied; the effects of waste weirs or outlets were analyzed; daily records of river stages at many points were established; sediment observations were made; in fact, the whole range of river physics was fully covered.

While this was under way, the amelioration of conditions in the delta region from near the mouth of the Ohio to the Gulf of Mexico received immediate attention, owing to the large area subject to overflow (sometimes 60 miles or even more in width) which required protection from floods. The principal source of these floods is in the Ohio Basin, with its heavy spring rainfall and the steep slopes of its tributaries. The sources of the floods that menace the Lower Mississippi are not always in the same drainage basin, nor in the head-waters thereof. The floods of 1844 and 1903 were from the Lower and Middle Missouri and the Upper Mississippi; the floods of 1912-13 were from the Lower Ohio Basin Districts. The floods of 1882-83-84 were largely from the upper portions of the Ohio Basin and its tributaries. This shifting of the locus of the floods over such great areas prevents reservoir control. The delta area lying below the flood level is shown in Fig. 26.

The advocates of flood control for this district were divided into three groups, namely, those who favored reservoirs; those who favored outlets as the only solution; and those who regarded the experience of about two centuries with levees for partial flood control as sufficient to justify the use

of them for complete control. Others asserted that the floods could not be controlled and that no attempt should be made to curb them, but that mounds should be built for occupation by the people and their live stock while the lands were flooded. The digging of another river channel from the Ohio to the Gulf equal to that of the Mississippi was also urged on Congress.

The Commission undertook a study of all these plans for flood control and concluded that reservoirs to prevent floods along the Lower Mississippi were impracticable, owing to the great number and size required and to the lack of suitable sites for reservoirs for such large volumes of water. Judging from the cost of the flood control of the comparatively small Miami Basin, of $32 000 000, the conclusion of the Commission as to reservoirs is manifestly correct.

The effect of outlets was given careful consideration in the study of the action of existing outlets. There can be no outlets above the mouth of Red River, that would relieve the river of flood water without returning it again at a lower point, therefore, the major portion of the delta basin would be overflowed before an escape could be reached. Extended observations, and many measurements, also showed that the reduction of volume, by means of secondary channels, of an alluvial stream, flowing in a bed of its own formation, will reduce the capacity of the main stream and, ultimately, will result in an increased flood height at and near the point of diversion. Therefore, the conclusion was reached that ultimately all outlets above the head of the Passes should be closed.

The depleted section of the channel just below the point of diversion can be restored to its normal capacity only by closing the secondary channel and by a quantity of water in the main channel equal to or greater than that before the diversion occurred. No scour by a lesser quantity can completely restore the channel to its original capacity, and the result will be that the permanent reduction of flood height hoped for, will not be realized. In brief, it may be said that a sedimentary stream flowing in a bed of its own formation tends to adjust its cross-section to the volume it carries.

Many cases could be cited to justify this conclusion, but a single one will suffice. The Nita Crevasse (that is, break in the levee) about 60 miles above New Orleans, occurred in the flood of 1890 and reached a discharge of 402 556 sec-ft., about one-third of the discharge of the entire river, but the flood stage at College Point, about 5 miles below, was lowered less than 2 ft. The Niagara River with its cataracts and rapids has a normal discharge of about 200 000 sec-ft., or one-half the discharge of the Nita Crevasse. The Colorado River, which created such havoc in Imperial Valley, California, has a maximum discharge of 150 000 sec-ft. These instances could be multiplied many times, all showing that disappointment and failure must follow attempts to lower permanently the flood level and incidentally the grade line of the levees by means of outlets, spillways, or weirs.

The river, at bank-full stage, will carry about one-half its maximum discharge, which is about 2 000 000 sec-ft. at the upper end of the delta. This quantity is largely dissipated as it moves down stream, filling the adjacent

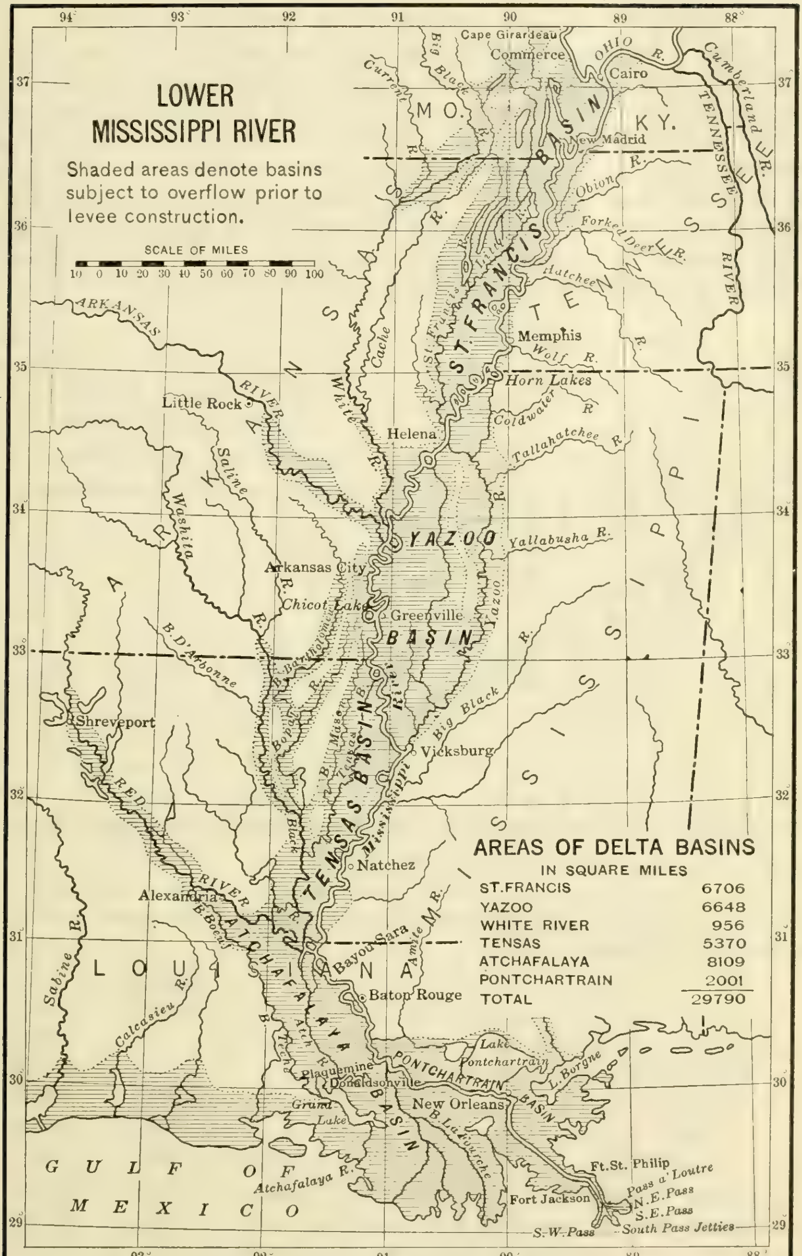

LOWER MISSISSIPPI RIVER
Shaded areas denote basins subject to overflow prior to levee construction.
SCALE OF MILES
10 0 10 20 30 40 50 60 70 80 90 100
AREAS OF DELTA BASINS
IN SQUARE MILES
ST.FRANCIS 6706
YAZOO 6648
WHITE RIVER 956
TENSAS 5370
ATCHAFALAYA 8109
PONTCHARTRAIN 2001
TOTAL 29790
Cape Girardeau
Commerce
Cairo
OHIO R.
Cumberland R.
TENNESSEE RIVER
MO.
KY.
New Madrid
Obion R.
Forked Deer R.
Hatchee R.
ST. FRANCIS BASIN
Memphis
Wolf R.
Horn Lakes
Coldwater R.
Tallahatchee R.
Helena
Little Rock
ARKANSAS RIVER
Saline
Washita
White R.
Cache
YAZOO BASIN
Yallabusha R.
Yazoo R.
Arkansas City
Chicot Lake
Greenville
B. D'Arbonne
Big Black
Vicksburg
TENSAS BASIN
Shreveport
RED RIVER
Natchez
Alexandria
Bayou Sara
Amite R.
Baton Rouge
Sabine R.
Calcasieu R.
ATCHAFALAYA
Plaquemine
Donaldsonville
Grand Lake
Lake Pontchartrain
PONTCHARTRAIN BASIN
L. Borgne
New Orleans
B. Lafourche
Atchafalaya R.
Ft. St. Philip
Pass a' Loutre
N.E. Pass
S.E. Pass
Fort Jackson
S.-W.-Pass
South Pass Jetties
GULF OF MEXICO
ARKANSAS
TENNESSEE
MISSISSIPPI
LOUISIANA

FIG. 26.

unleveed basins between the levees and the highlands, at the mouths of the tributaries, and the areas between the two lines of levees.

This huge reservoir, lying between the mouth of the Ohio and the Gulf of Mexico, a distance of 1 063 miles, covers an area of 5 000 sq. miles, or about one-half the area of Lake Erie. It is a reservoir that conforms to the high-water slope of the river, in which the water is continually flowing and at flood time emptying more than 1 000 000 sec-ft. into the Gulf of Mexico. Below the Ohio, the area between the high-water banks of the river is 1 000 sq. miles, no mean reservoir in itself, particularly when supplemented by levees 18 ft. or more in height. The discharge grows less as the crest of the flood progresses down stream, owing to the quantity taken up by the reservoir. This will be particularly marked with floods of short duration.

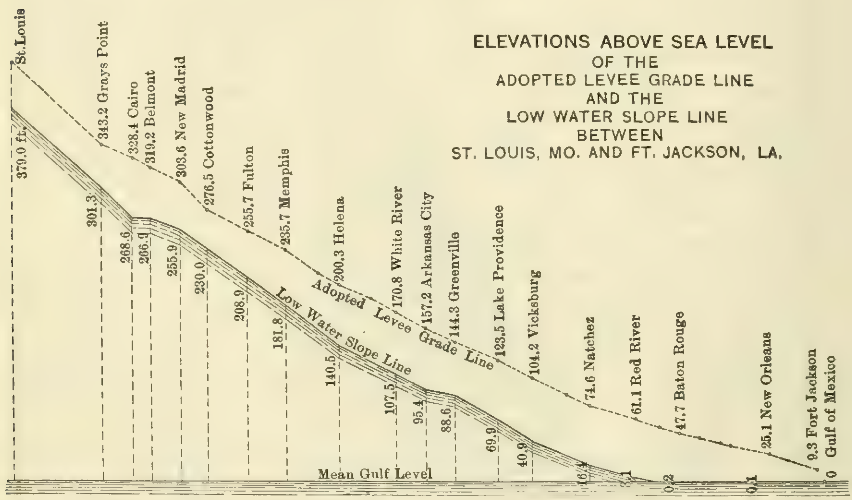


FIG. 27.

The oscillation of stage between extreme high and low water varies with the locality, as follows:

	Distance from Cairo, in miles.	Feet.
Cairo	...	55.7
Cottonwood Point	124	45.6
Memphis	227	49.2
Helena	307	58.2
Arkansas City	437	60.0
Lake Providence	542	54.1
Vicksburg	602	60.3
Natchez	706	54.3
Red River	773	53.8
Baton Rouge	841	44.2
New Orleans	965	22.6

On Fig. 27 are shown the low-water slopes of the river below the mouth of the Ohio, the distance between the successive stations being mid-river distances. The adopted provisional levee grade line is also shown. The levees fronting the great basins are called the controlling lines, and it is proposed to complete these before taking up the protection of smaller basins, most of which are hampered by difficult drainage if levees are built as a protection from floods.

The construction of levees for flood control began at New Orleans, in 1717, and by 1828 they had been extended, on the left bank, to Baton Rouge and, on the right bank, to the mouth of the Red River. Some measure of flood control has been in effect in this reach for about 200 years, but the levees in the beginning were small and breaks were frequent.

As the river banks became settled, levees were built, and, by 1860, all the great delta basins had some measure of flood protection in detached lengths of levee. At that time, the levees averaged about 4 ft. in height, whereas, to-day, they average about 18 ft.

The small levees of the early days were built by slaves, with wheel-barrows and scrapers, as evidenced by an Act of the Louisiana Legislature in 1860 which recites: "Providing for the sale, for cash to the highest bidder, by the Governor, of all slaves belonging to the Internal Improvement Department of the State, except four Engineers * * * to be selected by the Chief Engineer of the State." The word "Engineers" is capitalized in the text and relates to stationary or steam engineers, but, in itself, suggests no distinction between the technical, professional engineer and the non-technical mechanic.

In 1850, the Federal Government granted to the several States along the Mississippi all the unsold swamp and overflowed lands below the Ohio, the purpose being to provide a fund for reclaiming the inundated land, and this gave a decided impetus to the construction of levees. Even up to 1882, when the Federal Government again came to their relief, through the Mississippi River Commission, flood control by the use of levees did not meet with general approval, owing to the many disastrous failures (712 breaks in the floods of 1881-82-83), although competent Engineer Boards had repeatedly declared that flood control could only be realized by the use of adequate levees.

It was claimed that the construction of levees caused the bed of the river to be raised and, consequently, they would defeat their own purpose. A distinguished man, formerly a U. S. Senator, wrote that he was "reliably informed that the bed of the river was higher than the adjacent land," all caused by the construction of levees. To secure definite information on this subject, extended investigations were carried on, that resulted in establishing the fact that there has been no progressive elevation of the bed of the river due to levee construction. On the contrary, the latest comparison of cross-sections shows that there is a well-defined tendency toward a cross-section of greater capacity, including a lowering of the bed of the river.

To insure flood control on the Lower Mississippi River, it became apparent that levees, earthen dikes, or embankments, must be used, and this plan was adopted by the Commission, the purpose being to protect the delta basins

from any combination of tributary floods such as have occurred within historic times.

After centuries of successful use of levees for flood control on the Po and Theiss Rivers in Italy, the Nile in Egypt, and even in Louisiana, it was hard to account for the organized opposition to levees along the Lower Mississippi. This opposition, however, has largely disappeared with the success of the flood protection already obtained from the partly completed levee system.

Prior to the construction of levees, the floods of the river covered a width of 60 miles, as shown by the shaded areas of Fig. 26. The floods, laden with sediment, overflowed the channel and deposited the major portion of their load near the river banks, and this, in time, developed a land slope, away from the river, of from 3 to 15 ft. per mile. The natural drainage, therefore, is inland, toward the highlands bounding the delta. The drainage there enters tributary streams along the foot-hills, and these, in turn, empty into the Mississippi at the lower end of the several basins, such as the St. Francis, the Arkansas, the Yazoo, etc. Nature has greatly simplified the problem of flood control by making the drainage of the flooded lands, in the larger basins, comparatively simple.

To bring the vast expanse of water covering the great basins under control between levees, sometimes less than a mile apart, and further complicated by tributary inflow, made the determination of the required levee grades a difficult problem, but the elevations deduced, proved to be fairly close approximations. As 1 500 miles or more of levee are required to protect the great basins from floods, it was early decided to give as great a measure of protection each year as the funds available would permit, rather than attempt to begin at one end and complete the levee as the work progressed.

At present, the levees are completed to standard grade and section for about 500 miles. The entire length of the controlling levee line is to a grade that will withstand normal floods and the practice is to complete the levee to standard grade and section, from the up-stream limits of the respective basins, as the work progresses.

The standard levee section adopted has a crown width of 8 ft. at 3 ft. above the highest flood stage and has side slopes of 1 on 3, supplemented on the land side, by banquettes 20 ft. wide for levees from 10 to 13 ft. high, 30 ft. wide for levees from 13 to 16 ft. high, and 40 ft. wide for levees more than 16 ft. high, the tops of the banquettes being from 5 to 8 ft. below the tops of the levees.

The ground on which the levee is built is carefully prepared, first, by the removal of trees, brush, logs, and débris of all kinds. It is then grubbed to insure the removal of stumps, roots, drift, logs, and other unstable matter, so that the foundation will be of clean, compact, homogeneous earth. A muck ditch, about 5 ft. wide and 6 ft. deep is then cut along the axis of the levee as a further insurance of the elimination of perishable material. The surface is then broken and turned to a depth of 6 in. On this foundation, the levee is started full width and carried regularly, in layers not exceeding 3 ft. in thickness, to the full height. Only clean earth, free from foreign matter, is used in the levee.

The shrinkage allowance is 15% of the net fill, for scraper work, 20% for wagon work and 25% for dragline and other machine scrapers. This allowance for shrinkage is disposed on the top and the slopes so as to leave plane surfaces from the edge of the crown to the base, when shrinkage has ceased.

The earth is taken from a borrow-pit, usually on the river side of the levee, leaving a berm 40 ft. in width. The pit, beginning at the berm, is 3 ft. deep and from that point outward may be deepened on a slope of 1 on 50 and excavated so as to afford thorough drainage at the back of the pit.

After completion, the levees are sodded with Bermuda grass, which affords excellent protection from erosion by rain. Where levees are exposed to wave action, a layer of concrete about 4 in. thick or a board protection is used to break the force of the waves. Severe tropical Gulf storms below New Orleans make necessary substantial protection of the levees from wave action.

The bearing power of the soils on which the present high levees are built is, in some cases, not equal to the load placed on it and subsidence, which is not easy to overcome, takes place. Subsidence sometimes results in the bulging up of the adjacent soil several feet in height and an embankment, to hold a head of perhaps 20 ft. of water on a foundation of that kind, is far from satisfactory. Subsidence of that character in time of flood would be disastrous, but fortunately it occurs during the construction period when precautions are taken to overcome it by adding more material.

The extent of saturation in a levee depends on the character of the soil of which it is built, the length of time it is exposed to the flood, and the depth of water against it.

Experiments show that the hydraulic gradient, or the line between the wet and the dry earth in a levee, has a slope of about 1 on 5. To make the levee secure, this line should fall well within the base, hence the necessity of reinforcing the levee with a banquette.

The wheel-barrow and scraper have been superseded by the dragline, by cableway excavators, and by dump wagons hauled by tractor; the last promises largely to replace mules and wheel scrapers. Caterpillar traction, for large dragline machines, is in use and is regarded favorably. The tractor dump wagons have a capacity of 3 cu. yd. and are filled by steam shovels or by the ordinary elevating loader, also drawn by tractor.

The revolving dragline levee machine is equipped with a 5-cu. yd. bucket and a 165-ft. boom. The cableway machines have a span of 600 ft. or more and carry a 6-cu. yd. bucket. It is estimated that, under favorable conditions, one of these large machines will handle 400 000 cu. yd. during an average working season, the length of the season depending on the amount of rainfall and the duration of high-stage river conditions.

Much of the levee work is through heavy timber which must be thoroughly cleared and grubbed so that stumps or roots will not interfere with the operation of the bucket. As the embankment must be free from such foreign matter, the closest watchfulness is required to prevent a stump, hidden in the huge bucket of earth, from being dumped into the embankment.

During prolonged floods, sand boils occur on the land side, sometimes several hundred feet from the levee. These are caused by water, flowing through

the soil underneath the levee, breaking through to the surface in the shape of bubbling springs. As long as these springs carry only clear water, they are harmless, but should sand or sediment appear, prompt steps are taken to check them by impounding the flow. Earth-filled bags are used to create a head of water on the river side sufficient to check the flow.

During excessive flood periods, low-grade levees are topped from 3 to 5 ft. with earth-filled bags, which have been effective in preventing the levees from being overtopped, an active cause of crevasses and devastating floods. The erosion of the river banks has been and still is active in the destruction of levees. Fortunately, this is far more active during falling stages of river and with few exceptions never occurs during flood stages. In many places, active bank erosion has made it necessary to rebuild the lines of levees several times; particularly is this true of the earlier work in which the levees were placed too near the river bank. The present practice is to locate the levee so that it will be safe from normal bank erosion for at least 20 years.

The remedy for bank erosion is the revetment, which has been developed by the engineers of the Mississippi River Commission. There are three general types, namely, willow mattresses, articulated concrete mats, and solid concrete mats.

The willow mattress, in general use above Vicksburg, Miss., which is of the fascine type, is made up of bundles of willows held together by wire cables and heavy poles bound to the fascines by galvanized wire. These mats are generally made in lengths of about 1 000 ft. and are 250 to 350 ft. wide, depending on the depth of the water. Such a mat requires more than 100 acres of willow brush for its construction.

The head of the mattress is a bundle, about 3 ft. in diameter, of strong hardwood poles, 5 to 8 in. in diameter, with a length equal to the width of the mat, which forms the connecting link between the mooring cables and the mattress. The mooring barges are placed normal to the shore and serve to protect the mattress from accumulations of drift while it is afloat and also to support the head of the mattress while its construction is in progress. The ¼-in. steel weaving strands are also attached to the mat head.

For fascines, brush from 2 to 6 in. thick at the butt end, is placed in the forms, with the tops in the first layer in one direction and for the second layer in the opposite direction, care being taken to break joints. Enough brush is used to make a fascine 12 to 16 in. thick, when tightly compressed with a binding of No. 12 wire at intervals of about 8 ft., the length of the fascine being the same as the width of the mat. It is then moved down the ways to its proper place in the mattress, where the weaving strands are passed around it and also around the bottom longitudinal cables running the whole length of the mat.

The fascine is drawn taut to its neighbor by means of block and tackle, using a special clamp for the purpose. This process is repeated until the required length of mat has been reached. Rows of poles extending the entire length and width of the mat are then placed at intervals of 16 ft., and are securely lashed to the fascines by steel cables. The poles serve to keep the

rock from sliding off the mat while it is being sunk to the bottom of the river, and also to add strength.

The ballast required for sinking and holding the mats in place amounts to 1 600 lb. per square of 100 ft., and consists of stone blocks, each weighing about 40 lb., evenly distributed over the surface. An essential feature of these mats is that they must be woven so closely and so thick as to prevent the current from scouring through them. Fig. 28 shows a mat in the process of weaving. In sinking, the whole surface is first uniformly covered with as much stone as the mat will sustain, after which the head is weighted and lowered to the bottom and the sinking of the mat follows from the upper end down stream, by uniformly distributing stone from barges as the mat sinks.

The mat now covers the subaqueous bank from the shore line and extends well beyond the thalweg. The above water bank is then graded to a slope of 1 on 3 or 4 and paved with 10 in. of hand-laid riprap or with 4 in. of 1 : 3 : 6 concrete in lieu of the stone. The willows for the fascine mats described are cut, loaded on barges, and transported to the site of the revetment, where they are unloaded as the weaving of the mat progresses. This work requires a great deal of floating equipment.

Below Vicksburg, a type of framed mat is used, that is built on the river bank where the willows are cut and then is towed to the place where it is to be used for revetment. The mat is a brush raft made in sections, 100 by 150 ft., and when thoroughly compacted is 16 in. thick. In building this mat, frames are laid at 10-ft. intervals across temporary launching ways. These frames are filled with three layers of willows from 3 to 6 in. in diameter at the butt end, the middle layer being placed at right angles to the upper and lower layer. These layers are tightly compressed and a top frame is placed and firmly connected to the lower frame by posts and wooden pins. Cables or wire are not used in these framed mats, except for connecting several cribs together, in order to obtain the desired size for sinking.

The great quantity of willows needed for revetment soon revealed the fact that the supply could not long meet the demand, and studies were begun to develop other types and materials for use in bank revetment. Engineers naturally investigated the possibility of the economical use of concrete. Although many difficulties were experienced, two types were developed, one of which has been tested to such extent as to justify the belief that it will prove to be economical and stable.

The articulated concrete block system was developed by the engineers of the Vicksburg District. The blocks or mat units are 3 in. thick, 11½ in. wide and 3 ft. 11 in. long, reinforced with 12-in. wire mesh. This type has an advantage in that the block units can be prepared in advance, when river conditions are unfavorable for placing the mats. A 1 : 2 : 3 concrete is used for the blocks, and, three hours after pouring, the forms are removed and relaid for the next pouring.

In sinking, the mats are laid in position on a mat-building platform and fastened to a ½-in. wire rope at intervals of about 4 ft., thirty-five units forming a section of mat 25 by 140 ft. This section is launched and is fol-

lowed by succeeding sections, all of which are connected, until the required length has been obtained, the whole resting on the river bottom. An idea of the mat in process of launching may be gained from Fig. 29. This type can be laid at high water in case the upper bank has been previously graded to the proper slope. About 20 000 lin. ft. of this revetment has been successfully laid at a cost somewhat greater than the fascine willow mat.

Another type of concrete mat, developed in the Memphis District, provides for reinforced concrete laid in sheets, 50 by 150 ft. by 3 in. thick. This type of mat is sunk in a semi-plastic state from supporting trusses, by pulling the launching barge out from under it and lowering it to the bottom. The mat on the launching barge is shown in Fig. 30. The mat, partly suspended, as the barge is being withdrawn, is shown in Fig. 31. The supporting cables are tripped at the same instant the slab is in position for sinking, a short distance below the water surface. With this kind of plant, it is estimated that 4 000 lin. ft. of channel mat can be laid per month at a cost not far in excess of the willow mat.

This type of mat has not yet been tested to such extent as to develop fully its defects. When these are discovered and remedied, it seems probable that its economical use in bank revetment will result.

Methods of bank revetment have been discussed only in a general way, as this paper is primarily on flood control and relates more directly to the navigation feature of the work of the Commission, which requires it to "correct, permanently locate, and deepen the channel and protect the banks of the Mississippi River." The cost of revetment during the period of high prices incident to the World War, has been about $73 per lin. ft. of river bank. Prior to 1918, the cost was about $34 per lin. ft.

The Substantial Benefits Resulting from Flood-Control Work.—In what was formerly the area subject to overflow in the States bordering on the Lower Mississippi River, there have been extraordinary developments that must be largely credited to successful flood-control work. Without such work, even moderate development would have been impracticable.

In order to ascertain the extent of the benefits of flood control under the Mississippi River Commission, data have been taken from the United States Census reports of 1900, 1910, and 1920, that relate to the increase in farm areas, farm values, and population, as compared with like items in the non-delta parts of the States that are above the reach of Mississippi River floods.

The counties lying wholly or largely within the overflow basins of Missouri, Arkansas, Mississippi, and Louisiana, are included in these investigations. The census data are given by counties, a few of which contain considerable hill areas, and a sharp line as to flooded area alone, which is by far the major part of the area considered, cannot be drawn.

At the lower ends of the delta basins, the Upper St. Francis, Lower St. Francis, Yazoo, White, and Tensas, where tributary streams enter the Mississippi River, the levees are not completed, and the delta lands are subject to overflow to some extent from back-water, but the counties in which these lands are situated are included in the general investigation of benefits. With limitations in mind, the favorable results of the work done should be highly

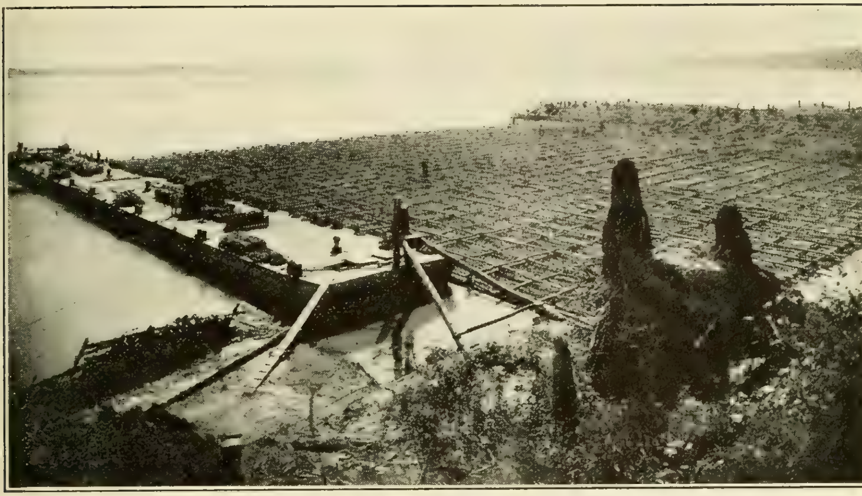


Fig. 28.—View of Mat in Process of Weaving.

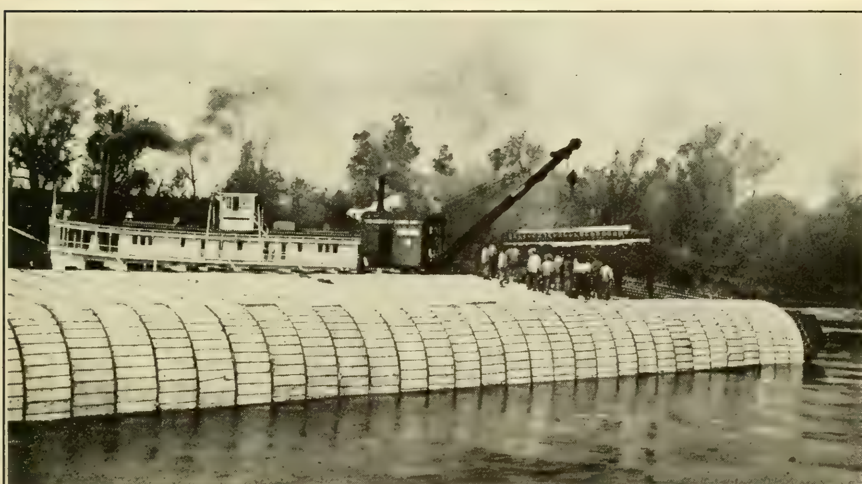


Fig. 29.—Articulated Concrete Mat Prepared for Launching.

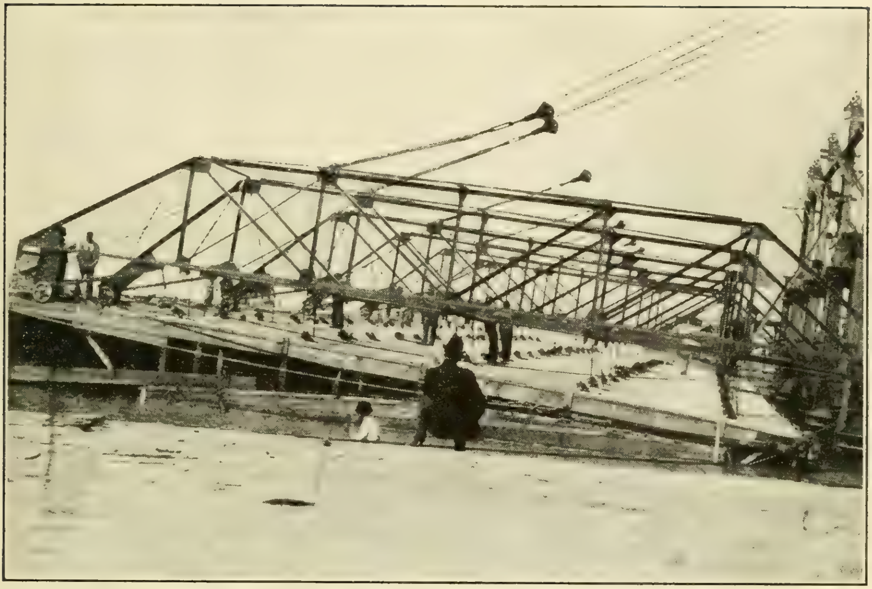


FIG. 30.—VIEW OF MAT ON LAUNCHING BARGE.

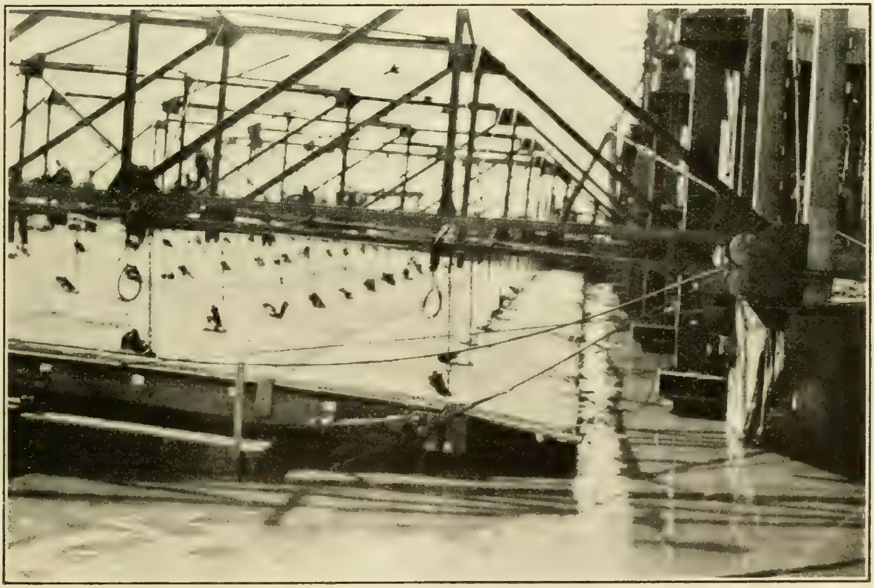


FIG. 31.—MAT PARTLY SUSPENDED AS LAUNCH IS BEING WITHDRAWN.

gratifying. The delta counties lie in the area formerly overflowed from the Mississippi River.

The State of Missouri has 114 counties, 6 of which lie in the delta, known as the St. Francis Basin. In these six delta counties, the total value of "all farm property" in 1900 was $25 118 167 and, in 1920, it was $170 079 705, a gain in value of $144 961 538. The percentage of increase is about two and one-half times that of the State at large. The total acres of "improved land in farms" in 1900 was 604 475 and, in 1920, it was 1 072 133, a gain of 467 658 acres, which is more than one-fifth of the gain in all the other counties of the State combined.

The average price per acre of "land in farms", has increased from $19.72, in 1900, to $101.37, in 1920, whereas in the State at large the increase has been from $20.46 to $74.60. The population has increased 55 912 in the same period, whereas 89 counties show a decrease in population and more than one-fifth of the total gain for the entire State, including cities, belongs to the six delta counties.

The State of Arkansas has 65 counties, 7 of which lie along the Mississippi River, largely in the delta district, but also embrace considerable areas of hill lands. In these seven counties, the total value of "all farm property" in 1900, was $22 602 988, and, in 1920, it was $168 390 215, a gain of $145 787 227, which is about one-fifth of the increase for the entire State. The total acres of "improved land in farms" in 1900 was 592 151 acres, and, in 1920, it was 1 024 946, a gain of 432 795 acres, which is about one-fifth of the increase for the entire State. The average price per acre of "land in farms" increased from $12.32 in 1900 to $77.34 in 1920, whereas in the State at large, the increase was from $6.32 to $34.86 per acre. The population increased from 120 079 in 1900, to 220 442 in 1920, a gain of 100 363, which is about one-fourth of the total gain for the entire State. The cotton acreage increased from 341 222 acres in 1910 to 539 550 acres in 1920, with an increase of 69 493 bales of cotton in the same period.

The State of Mississippi is divided into 82 counties, 12 of which lie in the delta. In these delta counties the total value of "all farm property" in 1900 was $60 071 432, and, in 1920, it was $442 481 342, a gain of $382 409 910, which is equal to one-half the gain for the entire State. The total acres of "improved land in farms" in 1900 was 1 466 413, and, in 1920, it was 2 067 384, a gain of 600 971 acres, which is equal to one-third of the gain for the entire State. The average price per acre of "land in farms" increased from $17.29 in 1900 to $121.61 in 1920, whereas in the State at large, the increase was from $6.30 to $35.27 per acre. The population increased 107 850 from 1900 to 1920, whereas 49 of the counties show a decrease. The population of the State at large increased 293 348, including the cities, but 38% of the gain was in the delta counties. The cotton acreage increased from 1 023 353 acres in 1910 to 1 209 639 acres in 1920, or a total of 186 286 acres, with an increase of 64 026 bales of cotton in the same period.

The lower end of the Yazoo Basin is subject to overflow from back-water, as the controlling levee line is not completed for a distance of 18 miles, and the completion has been deferred so long that a considerable area of cultiva-

tion has been abandoned. Owing to this and the ravages of the boll weevil the development is greatly reduced from that which would have been realized under normal conditions.

The State of Louisiana cannot be analyzed in the same manner as the other Lower Mississippi River States, because one-third of its area is alluvial or delta land, its years of settlement are measured in centuries, and some measure of flood control has prevailed for a like period. There are about 2 000 000 acres still subject to overflow from the Mississippi and the full benefits from flood control will not be realized until this vast area has been reclaimed.

Thus far, the benefits are largely the result of the more substantial levees, which give added security to the lives and property on land that has long been in use, rather than to any great extension of new areas of farm land.

The benefits are reflected in the farm land values, which have increased from an average of $15.05 per acre, in 1900, to $46.51 per acre in 1920, as derived from fifteen parishes fronting on the Mississippi River.

The Commission has assigned to a special committee of its members the task of preparing a full report of the work done under the Mississippi River Commission and the results attained, "in order to bring together with a view to publication and make available the great mass of valuable data relating to river hydraulics, covering physical investigations of the varying elements that make up the regimen of the Mississippi River, as well as the methods and instrumentalities that have been developed and tried out by the Mississippi River Commission and its assistants in channel improvement and flood control of the river." This work is now in progress.

MISSOURI RIVER BANK PROTECTION AT OMAHA, NEBRASKA

By Roy N. Towl,* M. Am. Soc. C. E.

Current retards have been used with good results at Omaha, Nebr. All other types of bank protection heretofore used have been destroyed by the Missouri River, which has swift scouring flood currents, a shifting bed of sand, and alluvial banks subject to erosion.

The current retards, or pervious dikes, are made of whole trees (from 8 to 30 in. in diameter), built out from the shore a distance of 100 to 300 ft. The butts of the trees, which are placed up stream, are tied together with steel cables, held by bank cables running to "deadmen" on shore, and permanently secured with interlacing pile cables to a row of submerged concrete anchor-piles placed 35 ft. apart and 100 ft. up stream from the retard. By using these reinforced concrete anchor-piles, the problem of security against deep scour has been solved.

A pile 20 ft. long and 14 in. square has a center 4-in. jet pipe reduced to a 1-in. nozzle. It is equipped with three ½-in. upturned jets on each side. With a constant water supply at a pressure of 200 lb. per sq. in., the pile becomes an hydraulic giant excavator.

The center jet digs down and the twelve side jets lubricate the sinking pile and remove side friction. Within 10 or 15 min., the 20-ft. pile is sunk to a depth of from 75 to 100 ft., which is below the limits of scour of the river. The 4-in. hose connection is removed without shutting off the water supply. Six or more cables are attached to each anchor-pile before sinking.

The pile is not hammered and rests in final position in perfect condition. As soon as the water is shut off, the material through which the pipe has penetrated settles firmly around it.

A pile of any length can be sunk to any depth through any material that can be displaced under water pressure. The length and weight of the pile are limited only by the capacity of the handling equipment. A 50-ft. test pile sunk in the sandy soil of the Platte Valley carried 100 tons without settlement.

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* Omaha, Nebr.

FLOOD PROBLEMS IN THE ARID REGION

By Arthur P. Davis,* Past-President, Am. Soc. C. E.

A stream of water, whether the smallest rill or the largest river, generally has a definite channel of sufficient capacity to carry its waters in ordinary stages. When these stages are exceeded, some streams overflow their banks, and this gives rise to flood problems. Not always, however, can a stream overflow its banks even in the highest stages.

The Colorado River furnishes an illustration of a stream which can not overflow its banks in some parts, but which can and does do so, at frequent intervals, in others. Throughout the canyon region, where the main stream and its tributaries are rapidly eroding their channels, there is no opportunity for the formation of valleys, and the sides of the canyon are much higher than the summit of the largest floods. In its lower reaches, however, the river emerges from the canyon, and loaded with the sediment collected therein, traverses valleys which have been built of such sediment, and, in ordinary stages, follows its channel to the sea and there deposits its heavy load, building up a delta at its mouth and constantly increasing its length by this means. In order to maintain the grade necessary to carry the sediment, the river must build up its channel at a rate corresponding to the lengthening produced by delta formation at its mouth. This tendency is self-regulating. As the grade of the river decreases, its velocity and capacity for carrying silt decrease at the same time. Therefore, the stream deposits its sediment and builds up its bed, which has the effect of increasing the grade from that point down. It has also the effect of increasing the tendency to overflow and, by such overflow, causing a deposit of sediment in the flood-plain.

Thus, every muddy stream like the Colorado or the Mississippi is increasing its length and building up its flood-plain by overflow. By this process, such rivers form great alluvial valleys attractive to agriculture and, therefore, to population and to the growth of cities. Many of the most fertile valleys of the world are flood-plains of great rivers which are threatened with a constant tendency to overflow and consequent damage to life and property. In some instances, this tendency is greatly aggravated by geological change. This is true of the eastern plain of China and of the lower reaches of the Amazon, where gradual geologic subsidence has made the middle course of the river lower than it would have been had it been built as a flood-plain without other modifying influences.

In northern latitudes, occasional floods may be caused mainly by ice gorges, which occur at times of moderate freshet. By obstructing the escape of water, they cause overflow out of proportion to the quantity of water involved. The majority of floods, however, are caused by excessive rain or by sudden melting of large snow accumulations or, frequently, by both these causes. The problem of control includes not only the study of precipitation, but the conditions

* Director, U. S. Reclamation Service, Washington, D. C.

affecting the opportunities for escape of flood waves, including slope and channel capacity. In most cases, the problem is many-sided. All the regions suffering by the floods, under investigation, must be studied, and the remedies proposed should be considered from the standpoint of their influence on all concerned. If a certain city is protected solely by means of levees and channel widening and rectification, such work will have no beneficial influence on the areas below, and it may even slightly increase the difficulty. If detention reservoirs are used, their effect must be carefully considered with respect to all interests down stream.

In general, the benefit of a detention reservoir must be mainly local. The flood problems of Dayton, Ohio, and vicinity have been solved mainly by detention reservoirs, which benefit flood conditions at that point and to a gradually diminishing extent below, but at some point down stream, the benefits of these detention reservoirs disappear or may even become negative. For example, in a widespread storm, the peaks of discharge from different tributaries generally reach the main stream at different times, and detention reservoirs on the stream from which, otherwise, the peak would arrive first, might delay it so as to make it simultaneous with that from the other stream and increase the maximum flow in the main stream. Some such combination is almost sure to happen occasionally in any large complex drainage system provided in part with such reservoirs; but if similar detention reservoirs are provided on both streams so that they are retarded by about equal amounts, this menace is eliminated.

Every great flood, such as that at Dayton in 1913, or that in Pueblo, Colo., in 1921, fixes attention on the immediate locality and necessitates the solution of its problems. At the same time, it calls attention to this menace in other regions, and one may be certain that, as population increases and time goes on, the necessity of solving flood problems will be brought more and more forcibly to public attention.

Storage for flood protection is, to a great extent, antagonistic to storage for other purposes. For irrigation, power, or municipal supply, the proper use of a reservoir generally demands that it be operated in such a way as to keep in storage the largest quantity of water consistent with the necessary draft for use, and these drafts are gradual and more or less regular. Flood prevention, however, demands that, as far as practicable, the reservoirs built for this purpose be held empty so as to receive and store the floods they are designed to control. Whenever a reservoir is used for both purposes there is a tendency for the dominating object to encroach on the domain of the other, and, in general, different reservoirs or distinct capacity in one reservoir, must be devoted to flood prevention and to the various uses required. Notwithstanding these tendencies, almost any large reservoir, even if devoted entirely to industrial uses, will have some influence in regulating flood waves. In many cases, the flood wave may reach a partly filled reservoir and to the extent of the available storage, the flood will be stored and thus controlled. Even if the reservoir is full at the time of maximum flood flow, the surface, if large, will serve as a flood regulator while the accumulating waters raise the level of the lake to the point where the spillway is accomplishing its

maximum discharge. Such a function is performed by every large lake and sometimes constitutes an important regulator on a river system.

Reservoirs provided by the Federal Government primarily for irrigation have sometimes proven important regulators of flood discharge. In 1909, the spring flow of the North Platte River greatly exceeded any previous record. The Pathfinder Reservoir received this flood flow, and, with all outlets opened to full capacity, the reservoir was nearly filled by the time the river reached its maximum discharge. The results of that season's experience indicated that had it not been for the regulative influence of the Pathfinder Reservoir damages in the valley below, by the inundation of farms and towns and the destruction of bridges, would have amounted to nearly as much as the cost of the dam.

Material benefit in flood protection has resulted from the construction of the Roosevelt Reservoir, on the Salt River, Arizona, although it was not designed and is not operated for such a purpose. This is also true, in a less degree, of the Shoshone Reservoir in Northern Wyoming, the Boise Reservoir in Idaho, and others.

One reservoir of the U. S. Reclamation Service—the Elephant Butte Reservoir in New Mexico—has been designed and operated for both purposes, primarily for irrigation, and, secondarily, for flood control. Its capacity is large, and it is not expected to fill frequently, but when it does fill, it is likely to be in a year when considerable water would run to waste. The shallow river bed which extends through the highly improved valleys, overflows easily, and it is desired to restrict the flow to the capacity of the channel, or about 8 000 sec-ft. The drainage below the reservoir, normally dry, sometimes furnishes a flow of this quantity and, at such times, it is proposed to close the reservoir until the peak of the local flood has passed and, at other times, to limit the discharge from the reservoir to a quantity that the river channel can carry with safety. For this purpose, about 400 000 acre-ft. of capacity in the reservoir is reserved. As the water level approaches the spillway lip, it begins to discharge through four wells into tunnels passing under the spillway, and continues to discharge during the rise of the reservoir while filling the 400 000 acre-ft. capacity reserved for flood control. When the spillway begins discharging additional water, the wells will be closed at a rate to hold the discharge to the desired capacity, and as soon as practicable, without exceeding that capacity, the reservoir is emptied to the level of the wells.

The peak of the great flood will seldom coincide with the filling of the reservoir, but when this does occur it can be operated in the manner described and the discharge can thus be restricted to the safe capacity of the river channel below.

In past years, the floods of the Rio Grande have caused millions of dollars of damage to railroads and other property in its valleys. The damage would greatly increase with the increased settlement and development of the valley under irrigation, if it was not for the protection of the reservoir. With this protection, the damages will be reduced to a comparatively small amount. Such a result, however, depends on the fidelity with which the plan is carried out, by which a part of the reservoir is perpetually reserved for flood control.

The Sacramento River in California is subject to great freshets, which cause much damage in its valley. The State of California and the Federal Government are expending large sums in building levees and rectifying the channel. The results desired would be promoted and cheapened if the flood-control efforts could be co-ordinated with the storage works planned, which can be paid for mainly by the irrigation and power interests dependent on them. The storage proposed would not remedy the flood conditions, but it would reduce the peaks of the floods if storage space was reserved for that purpose and works were so operated. However, it has not been possible to co-ordinate the plans of flood control and water storage on this river to the extent that is desirable.

In the lower valleys, watered by the Colorado River, the menace of flood damage is important. The Gulf of California formerly extended northwestward to a point a few miles above the Town of Indio, or about 140 miles from the present head of the Gulf. The Colorado River emptying into the Gulf a short distance south of the International Boundary, carried for centuries its heavy load of silt, gradually building up a great delta cone entirely across the Gulf and cutting off its northern end, which remains as a great depression. Most of the water has evaporated from this depression leaving in its bottom the Salton Sea, 300 sq. miles in extent, with its surface about 250 ft. below sea level. The river flowing over its delta cone steadily deposits silt in its channel and on its banks by overflow, so that it gradually builds up its channel and its banks and forms a ridge, growing higher and higher until the stream becomes so unstable that it breaks its banks in the high-water period and follows some other course. In this manner, in past centuries, the stream has swung back and forth over its delta until this exists as a broad, flat ridge between the Gulf and the Salton Sea, and on the summit of this ridge has formed a small lake, called Volcano Lake, about 30 ft. above sea level. The direct distance from Andrade, where the Colorado River reaches Mexico, to the head of the present Gulf, is about 75 miles, and the distance to the margin of Salton Sea is about the same. As the latter is 250 ft. lower than the Gulf, the slope to the Salton Sea is much greater than to the Gulf of California. This condition, together with the inevitable necessity for such an alluvial stream to leave its channel at intervals, constitutes the menace to the lands lying about the Salton Sea, known as the Imperial Valley. As there is no escape for water from the Salton Sea except by evaporation, the river flowing into this sea, unless diverted, would gradually fill it to sea level, or above, and submerge the cultivated land and the towns of Imperial Valley.

In 1905, the river turned its entire volume into the Salton Basin, eroding a deep gorge and raising the level of Salton Sea. It submerged the salt works and forced the removal of the main line of the Southern Pacific Railroad. At great difficulty and expense, after many unsuccessful attempts, the river was returned to its old channel in February, 1907. The control of the river would be greatly facilitated if the floods were reduced in volume.

The declivity toward Salton Sea is so great that, when the river flowed in that direction, it rapidly eroded a deep gorge in the alluvium of Imperial Valley, and, in the process, formed several cascades which gradually retreated

up stream. If this experience should be repeated and the erosion continue for some time, it would cause great damage and the flood of the river in the deep gorge would be difficult to control. It is of first importance that these floods be diminished or abolished.

The most feasible point at which this can be accomplished is in Boulder Canyon at the northwest corner of Arizona where the river forms the boundary between Arizona and Nevada. At this point, it has been demonstrated as feasible to build a high dam forming a reservoir of almost any desired capacity up to 30 000 000 acre-ft. Such a reservoir would be able to control the entire flow of the Colorado River and permit its utilization for irrigation and power. By keeping 5 000 000 or 6 000 000 acre-ft. in the top of the reservoir as a reserve for flood control and utilizing the remainder available for other purposes, the flow of the Colorado can be confined to less than 25% of its maximum flood discharge.

The fluctuations of this river are such that a large reservoir capacity would be available for flood control coincident with its use for other purposes. The largest floods generally come in May or June, and the low-water season is in the fall and winter. By storing these floods, they would become available for useful purposes by increasing the low-water flow and, at the same time, the flood damage would be eliminated. It is true that the middle part of the basin is subject to floods at other times than the spring, and for this reason the maintenance of the 5 000 000 or 6 000 000 acre-ft. of capacity is necessary to care for such floods. The normal use of the stored waters through the low-water season is sufficient, however, to make available at the opening of the flood season in April, a capacity which generally will be about 10 000 000 or 12 000 000 acre-ft. This capacity will then be available for receiving and regulating the largest floods of the river, which are those that come at this season due to melting snows.

Other storage sites are available farther up in the basin, above the Grand Canyon of the Colorado, but these sites would not be satisfactory for flood control, because they would leave more than 50 000 sq. miles of drainage area uncontrolled.

To make the work complete, it would also be necessary to have a detention reservoir on the Gila River, which occasionally sends a short, flashy flood of destructive volume into the Lower Colorado. These flood waves, however, are so short in duration and so small in total volume that although they menace engineering works, they do not constitute such a material danger to the Imperial Valley as that involved in the long-continued spring freshets of the Colorado.

SOME FACTORS AFFECTING THE PROBLEM OF FLOOD CONTROL

By C. E. Grunsky,* M. Am. Soc. C. E.

Climate and topography introduce peculiar features in the flood-control problems on the Pacific Coast. This will be explained briefly and a few typical projects will be cited, in order to make the underlying principles of flood-control projects clear, rather than to attempt an exhaustive presentation thereof.

The big floods on the Pacific Coast (excluding Alaska from this discussion) occur in the winter or early spring months as the result of heavy rainfall continuing frequently throughout several days. The flood volume of those streams the drainage basins of which extend to high altitudes where there may be much snow on the ground, may be considerably augmented, at times, by the rapid melting of the snow under the influence of what is generally termed a warm rain. As far as is known, however, it appears safe to attribute peak discharges to rain of the maximum possible intensity, as this maximum intensity without any addition of snow may be assumed to be as effective in producing maximum flood conditions as any warm rain that is likely to fall when there is much snow on the ground.

The great cyclonic storms covering vast areas, as they sweep easterly from the Pacific Ocean, are usually accompanied by gentle rainfall continuing for several days. As the storm passes and the wind swings from southeast to southwest, the intensity of the rain increases, it becomes colder, and presently the wind will blow from the northwest and the storm is over. The storm may be followed immediately by others, and it is the heavy rains in these second and third, or later, storms, which are predisposed to produce extreme flood conditions. When a winter season is of the wet type, the rain that falls during these "trailers", finds the ground already saturated and a large part of the rain water must go to the stream. Another noteworthy peculiarity of the Pacific Coast storms is that they are not of the intense type of thunder-storms of the Atlantic Coast and Middle West. Thus, for example, from 2 to 4 in. of rain per hour may be expected on relatively small water-sheds in the East, whereas, on the Pacific Coast, it is rarely that 1 in. per hour is exceeded. Another difference is that there is no ice in the lower reaches of the Pacific Coast streams, and floods due to ice jams do not occur; neither is frozen ground to be taken into account on any of the larger Coast streams.

The drainage basins of the larger streams of the Pacific Coast extend into high mountain regions and parts of these basins may be covered with snow, which is compacted more or less by the occasional rains. Therefore, at the close of the wet season, the ground may be covered with 5 or 6 ft. of packed snow. There is shrinkage at times as the season progresses; this shrinkage, however, does not always represent melting, but may be due, in large part, to the compacting that results from rainfall on light snow and from the melting of surface layers of the snow, which forms water that sinks into and aids in compacting the lower layers.

* Cons. Engr., San Francisco, Calif.

No definite statement can be made as to the maximum rate at which the snow in the mountains will melt under the influence of the rising temperature and the greater warmth of sunshine when winter is past, but this rate is not productive of the extreme flood conditions of the river. Generally, the rain and snow storms that produce flood conditions, are most frequent in January. They begin to decrease in frequency and duration in February, occur rarely in April, and, after May 1st, no storms are expected that will have any great effect on the flow of the stream in its valley course.

It will be apparent that extreme flood conditions are most likely to occur in midwinter and that the larger rivers of the Coast and those fed by mountain snows will have a long sustained spring and summer high stage. The snow has a beneficial effect in prolonging the time during which the streams are at fair stages. The hydrograph of the San Joaquin and Sacramento Rivers, for example, may show a number of peaks representing the flood stages in winter and then a long sustained moderately high stage, usually terminating in July. The tributaries of these rivers from the east, that is, those which flow into the valley from the snow-capped Sierra Nevada Mountains, behave in a similar manner. This feature makes these streams particularly valuable for irrigation. Even the Colorado and the Columbia partake of similar characteristics when their lower reaches only are considered. Their flow is little influenced by the later summer storms, in the high Rockies, which storms are usually of local character and cover little territory.

On Pacific Coast streams, the flow in the late summer and fall dwindles to insignificance, except where a part of the water-shed is porous and the flow is equalized somewhat by the release of water from underground storage. Thus, for example, the Sacramento River, at and below Red Bluff, would go nearly dry in the fall, if it was not for the great volcanic beds of the Mt. Shasta and Mt. Lassen regions, which disgorge water long after the rainy season is past. The flow reaching the Sacramento River throughout the year from such sources is about 4 000 sec-ft., and its principal tributary, Feather River, receives about 500 sec-ft. from similar sources. In its valley section, the San Joaquin River receives a return flow from irrigated lands, of more than 300 sec-ft. and this quantity is expected to increase with the prospective greater use of water for irrigation.

The effect of deforestation on the magnitude and frequency of floods on the Pacific Coast will only be briefly discussed. The timber has been removed in the usual wasteful manner customary in the United States, but this removal has nowhere had any demonstrable effect on the run-off from drainage basins of considerable extent. The clearing of land for farms has been relatively small and, usually, there is so much young timber and other vegetation on the cut-over lands, that the ground has substantially the same degree of protection as under natural conditions. No facts can be cited that will throw any light on the effect of the forests on either the frequency or the magnitude of floods.

The following characteristics of the problems on the Pacific Coast are noted:

1st.—The river flows through a valley the surface of which slopes from both sides toward the river. Such is the Columbia River in its lower reaches

and the Sacramento River in the upper part of Sacramento Valley, from Red Bluff to the mouth of Stony Creek, and the San Joaquin River throughout most of its valley course.

2d.—The river debouches on valley land, with a bed slightly depressed below the general surface of the ground, and "fingers" out, sending its flood flow into a number of channels which generally lack permanency and which overflow at moderate, or high stages, sending their waters broadcast over the land toward the main valley drain. Examples of such rivers are the Calaveras, east of Stockton, the rivers of Los Angeles and San Bernardino Counties, California, and a number of lesser streams.

3d.—The river has built up high banks by the deposit of sediment and is flanked by depressions commonly called basins. The Sacramento River, from Stony Creek to Cache Slough, is of this type.

4th.—The area to be protected against inundation is a depressed area with no drainage outlet, such as the Tulare Lake region in California and the Salton Basin which extends from California into Mexico.

Where the floods of rivers of the first class are to be controlled, the problem involves either a regulation of the flow by storage reservoirs or protection by levees, of the area adjacent to the stream that is subject to submersion. Levees will reduce the storage capacity of the flooded area and will force up the flood-plain. The discharge at the peak of the flood will be increased, and suitable provision for adequate channel capacity in the lower reaches of the river must be made. This problem is now being worked out for the San Joaquin River, the particular question being the proper location of the levees—how far shall they be apart—and the increase of channel capacity at the upper end of the river delta. Fortunately, however, in the case of this river, reservoirs of large capacity are being planned on a number of tributaries of the stream the primary use of which is to be for irrigation. These reservoirs, supplementing storage for power purposes already aggregating about 600 000 acre-ft., will have some favorable effect on the flood flow of the main river. Even though all these reservoirs might be full when a great flood comes, they would, nevertheless, in some measure, elongate the flood wave and thereby reduce the peak discharge. Among these reservoirs, may be mentioned:

Pine Flat Reservoir on Kings River...........	600 000	acre-ft.
Madera Irrigation District Reservoir on San Joaquin River	600 000	" "
Excelsior Reservoir on Merced River..........	300 000	" "
Don Pedro Reservoir on Tuolumne River.....	250 000	" "
Melones Reservoir on Stanislaus River........	70 000	" "

The Don Pedro Reservoir is under construction and work on the Excelsior Reservoir may begin at an early date. The principal effect of such reservoirs will be to reduce the number of floods. They will probably have comparatively little effect on the maximum discharge of the extreme flood, which is expected only once or twice in a century. The reasonableness of this conclusion will appear when it is recalled that the normal annual water output of the San Joaquin River is about 6 000 000 acre-ft., but that the discharge, in seasons of heavy rainfall, may be 25 000 000 acre-ft., or more.

The flood-control problem on the Pacific Coast has been complicated, as in other regions, by human agencies and activities. For example, the lands that were submersible at high river stages along the Sacramento and San Joaquin Rivers under natural conditions were given by the United States in 1850 to the State of California to be reclaimed. Provision for the disposal of these lands to private parties was made soon thereafter, the first Act fixing the sale price of the land at $1 per acre and placing a limit of 320 acres on the area that a single person could purchase. A few years later, this limit was raised to 640 acres. In 1861, a State Board of Swamp Land Commissioners was created with authority to form districts and to expend $1 per acre on reclamation works. In 1862, the counties were empowered to levy assessments when the cost of reclamation exceeded $1 per acre. By 1865, there had been fifty-four Swamp Land Reclamation Districts formed. In 1866, the powers of the Swamp Land Commissioners were transferred to the county authorities and, two years later, the limit on the area permitted in single ownership was removed. Nearly all the swamp and overflowed land holdings of the State had been disposed of within three years thereafter. In 1874, the limit of area purchasable by a single person was restored to 640 acres.

In 1880, a Board of Drainage Commissioners was created by Legislative enactment but, a year later, the Act creating this Board was declared to be unconstitutional. In 1888, Congress authorized an investigation to determine the damage that had resulted in California to navigable waters by reason of mining operations and, in 1893, it created the California Débris Commission, which outlined the Sacramento Valley Control project, now well advanced.

Under the original program of the State, each owner of land subject to overflow was to be allowed to protect himself as best he could. When the lands were sold, no right-of-way reservations were made as no thought was given to the larger question of bringing the floods under control. Each landowner was permitted to build his own defenses, regardless of the effect of his levees on the stage of water in the river channel or on the spreading of the flood over adjacent lands. Under the resulting system, each landowner or each group of landowners was arrayed against the other; the owners on one side of the stream were pitted against those on the other. Each land-owner tried to outstrip his neighbor on the strength of his levee immediately in front of his property. "If the levee must break, let it be on some other man's land," was the prevailing sentiment. The landowner, living on the bank of the river, which under original conditions was barely submerged at the river's flood stage, soon found himself and his possessions behind a high embankment of earth, softened, perhaps, by long continued rains, with the water of the river steadily rising toward the top of this dike and the menace increasing, until somewhere the dike must give way. It is not surprising that under such circumstances he resented the fact that here and there the head of a swale, or high-water channel, leading away from the main stream, had been closed in the process of land reclamation and that the river had been forced to carry more water than Nature had intended. Thus, it sometimes happened that at the height of a flood, a dam, closing some such depression, would be cut, and the river would find relief, flooding the lands on the other side.

What should have been done at the beginning was not done until within recent years. There was no comprehensive flood-control project until, in 1908, the California Débris Commission, composed of members of the Engineer Corps of the U. S. Army, recommended the plan that was subsequently approved by both Congress and the State of California. By this time, however, the private attempts at reclamation were extensive. Bank lands, to a large extent, had become highly improved and many settlements, towns, and cities were firmly established on the river front. None of the overflowed land could be re-purchased for rights of way at a price anywhere near that at which the State had sold it, and when it came to providing for a passageway for the water which the river channel could not carry, the owners on each side of the valley wanted the burden thereof placed on the other.

The Sacramento River Flood-Control Project.—In its course through the Sacramento Valley, after passing the mouth of Stony Creek, the Sacramento River presents a peculiar problem. On both sides are flood basins into which, under natural conditions, there was large over-bank flow at every winter freshet and also during the protracted spring high stage. On the west side of the river are the Upper and the Lower Colusa Basins and, farthest down stream, the Yolo Basin. On the east side are Butte Basin, above the Marysville Buttes; then, Sutter Basin which lies between the Sacramento River and its principal branch, the Feather River; then American Basin just above American River; and, finally, Sacramento Basin, which extends south from American River into the delta region of the two rivers—the Sacramento and the San Joaquin—the waters of which intermingled at flood on a vast swamp-land area before reaching their common outfall point into Suisun Bay.

The Sacramento River, in its course between basins, occupies a deep channel flanked by narrow strips of high bank land. At some points, the banks are 15 to 20 ft. higher than the land ½ mile to 1 mile back from the river. The river, from a point known as Tisdale Weir, about 26 miles below Colusa, to the mouth of Feather River, about 44 miles, when at flood stage, can carry only about one-eighth of the water—30 000 sec-ft.—as compared with a total of 250 000 to 300 000 sec-ft. This condition which applies, in a somewhat less pronounced degree, to the other valley sections of the river, has led to the adoption of the following basic principles, in planning flood-control works:

(1) Confine to the river all the water that can safely be carried between well located levees of reasonable height.

(2) Allow the water in excess of the river capacity, thus created, to go over the bank at selected points under control.

(3) Prevent the general inundation of lowlands by confining this surplus water between embankments that will conduct it to a re-entry into the lower reaches of the river or into Suisun Bay.

The adopted project based on these principles includes the cutting off of bends and the widening and deepening of parts of the river. The most important channel enlargement of the project is that of the lower reaches of the river. The project has the effect of withdrawing vast areas of valley land from inundation, over which, under natural conditions, the floods could spread, the great basins acting as retarding reservoirs. Their withdrawal has the

effect of raising the river's discharge at the peak of the flood. In this respect, the Sacramento River flood-control project is diametrically opposed to that adopted at Dayton, where artificial retarding basins have been provided for the purpose of reducing the peak discharge.

When the basic principles previously mentioned were first presented by the speaker and his associate, Marsden Manson, M. Am. Soc. C. E., the fundamental consideration of prime interest to the individual landowner and to the State was the reclamation of submersible lands of the Sacramento Valley, almost 1 000 000 acres in extent. These lands were to be protected against overflow. Consequently, the preliminary suggestion did not involve the permanent exclusion of the lands in any basin from the benefit of flood protection. However, when the basic principles were adopted, some of the basins should have been reserved to serve permanently as retarding basins. The advantage of incorporating this feature in the final plan was not recognized and the project is being conducted on the original program. Only in the case of Butte Basin, which has little value as a retarding basin, has it been decided to permit the floods to spread. Sutter Basin is the one basin which obviously could have been of greatest service in reducing the maximum flood flow of the river, but the engineers failed to emphasize this fact and the reclamation of this basin to the total exclusion of flood waters has been permitted.

The flood-plain of the river for a flood stage similar to that of March, 1907,* was assumed, and elevations were fixed, which it is desired shall not be exceeded when there is a recurrence of such a flood. The height of levee tops above this flood-plain was fixed at 3 to 5 ft. Estimates were made of the quantity of water that the river channel can carry at such a flood stage and the places were selected at which relief would have to be afforded by providing outlets. At these points, such as the old Tisdale Weir, already mentioned, at Fremont, near the mouth of Feather River, and near Sacramento, concrete structures have been or will be provided, over the crests of which it is intended that the surplus water shall flow when the river stage approaches the danger line. At extreme floods, it is expected that several hundred thousand second-feet of water will get out of the river channel above Colusa. At the Tisdale Weir, 35 000 sec-ft. will leave the river. This water will be confined between earth dikes and led to a re-entry into the river at its junction with Feather River. As the capacity of the main channel below the Feather River is inadequate, further provision for relief has been made there. Fremont Weir, on the right bank of the river, will be provided, and the water passing over this weir will flow through Yolo Basin between dikes, or levees, which are to be about two miles apart. The areas between these levees have been called "by-passes". The work of constructing the river, the by-pass levees, and the relief weirs is now well advanced, and the flood-control project is nearing completion. Although no definite estimate is available of the effect which the reclamation of the up-river lands will have on the maximum flood discharge of the lower river, provision for greatly increased channel capacity is being made by dredging, which is being done by the Federal Government. The cost of the dredging is divided equally between the United

* *Transactions*, Am. Soc. C. E., Vol. LXI (1908), p. 281.

States and the State of California. The capacity of this part of the river is to be about 600 000 sec-ft. This capacity is to be compared with 200 000 to 250 000 sec-ft., which was a peak discharge at high flood stages before natural conditions were disturbed by human activities. In its lower reaches, the river is to be enlarged from an average width of about 1 250 ft. to 3 000 ft. Suction dredges are used for most of this work.

The by-passes are from a few thousand feet to several miles in width. In many seasons, they will receive very little water; there has been hardly more than a bank-full stage of the river for the last three or four years. Even in flood years, if unforeseen breaches in the river or by-pass levees do not occur, the by-pass areas, after a flood stage, will quickly drain and will be available for summer crops.

In 1889-90, as a member of the State Examining Commission on Rivers and Harbors, California, the speaker, in the report of that Commission, stated*:

"The State should modify its reclamation policy. All lowlands in or adjacent to the basins along Sacramento River, together with the delta lands of this stream, should be in one drainage district, and all similarly situated lands along the San Joaquin River should be in another, defined by competent State authority—by a State Board of Public Works—and all work for the improvement of drainage should be planned by such a Board, or under its supervision, and provision should be made to have the work paid for in proportion to benefits resulting therefrom." * * * "This Commission is unanimous in the opinion that * * * these waterways [referring to the Sacramento and San Joaquin River] should, in the interest of navigation, as well as to secure a rapid delivery of flood waters into the Bay, be so treated that they shall flow at their utmost capacity before any water is allowed to escape from them, and that no water should escape from any relief outlet whether natural or artificial, any longer than may be required to prevent a rise of water above a danger line, which should be established from time to time by competent United States or State authority."

After this report was made, more than twenty years elapsed before a comprehensive plan was worked out for the control of the floods of the Sacramento River. This plan was submitted to Congress in 1911 by the Secretary of War on the recommendation of the California Débris Commission. The estimated cost of the project was $33 000 000. Approval was given to the report of the California Débris Commission at a special session of the Legislature of California, in the same year (1911). In 1917, Congress adopted the project and committed the United States to an expenditure of $5 600 000 for the construction of relief weirs, the improvement and rectification of river channels, and the enlargement of the Lower Sacramento River below Cache Slough. The amount named was one-half of that still needed in 1917 for these features of the general project. The State is committed to furnish funds in like amount and the remainder of the cost is to be provided by the owners of the lands in proportion to the benefits. The total expenditure on the project to date has been more than $20 000 000.

A State Reclamation Board, composed of seven members, not only plans and directs the work, but also has some jurisdiction over private works of

* Report of Examining Commission on Rivers and Harbors, California.

reclamation and flood protection, which must be built to conform to the general features of the project.

For the Sacramento relief outlet, the City of Sacramento advanced the necessary funds and took charge of planning and building the structure. It is understood that, for this contribution, proper credit will be given in the final collection of assessments.

The White-Stuck and Puyallup Rivers Flood-Control Projects.—In the State of Washington near Tacoma is a problem with some unusual features. The White-Stuck and the Puyallup Rivers are being brought under control. The White and the Puyallup Rivers, which descend on steep gradients from the mountains to a coastal plain, carry great quantities of detrital matter and drift. The fall decreases where the flat coastal plain is reached and deposits of boulders and drift are likely to occur, which frequently are of such magnitude that the rivers are forced out of their channels. During a flood in November, 1906, the northerly channel of White River was thus clogged with drift and the entire flow was turned south into the Stuck Valley Branch, which enters the Puyallup River a few miles above the Town of Puyallup. Engineering studies of this situation have led to the adoption by King and Pierce Counties, of a joint flood-control project, of which W. J. Roberts, M. Am. Soc. C. E., is in charge.

Many engineering reports on this project have been made from time to time, from which a few noteworthy facts have been gained. It was found desirable to hold White River permanently on its new course through Stuck Valley, through which it originally sent only about one-third of its flood flow. The first estimates of channel capacity for flood discharge were too low, and, according to later estimates, a capacity of 65 000 sec-ft. is required. To secure this capacity, the channel of Puyallup River had to be straightened and enlarged, the old channel filled in part, and the banks protected against erosion. The northerly channel of White River was permanently closed by a dam, the concrete face of which had to be protected against undermining. Provision was made, also, for the interception and removal of drift.

Most of the channel excavation was done with a suction dredge, which, after the work was finished, was sold to the Imperial Irrigation District where they were used in keeping down the bed load of sand in the Imperial Canal. Various types of bank protection have been tried, several of which have been successful. Among these may be mentioned heavy concrete blocks strung together on wire cable, which blocks are 6 ft. long, 3 ft. wide, and 1 ft. thick. Another successful type of bank protection, used in the tidal sections of the river, was a concrete facing of the bank above low tide with an overlap of the concrete on a brush mattress which was well ballasted with rock or concrete blocks. The concrete bank facing is about 4 in. thick, laid in slabs, 10 ft. wide, separated by strips of wood 1 in. wide.

The device used for the interception of drift consists of a barrier of steel cables supported by thirty large diamond-shaped blocks of concrete, each block weighing about 330 tons. The total length of the barrier is about 2 000 ft., the openings between the concrete blocks being about 45 ft. in the clear, across which ten 1-in. steel cables are stretched. This barrier has functioned

quite successfully. After a flood stage, the accumulated drift is removed and burned.

The cost of the work on the White-Stuck and Puyallup Rivers from January, 1914, to the end of 1919, was about $1 630 000.

The Flood Problem of Los Angeles County.—The rivers of Los Angeles and San Bernardino Counties, California, present a problem with somewhat similar features. Only the San Gabriel and the Los Angeles Rivers need be cited as illustrative of the situation. The Los Angeles River breaks from its high mountain water-shed, 170 sq. miles in extent, debouching on a detrital cone which is composed of boulders, cobbles, gravel, and sand—a porous mass over which the waters of the river flow in ill-defined channels, the most significant characteristic of which is lack of permanency. There are no well-defined depressions to give direction to the water, and the channels left by the freshets are broad sand washes with occasional well-defined banks. The gradient of this part of the river's course is relatively steep. Along the ribs of the detrital cone, the fall is generally about 50 ft. per mile. The supply of detrital material seems limited only by the capacity of the river to carry it. When the major floods occur, they flow over the gravel cone at the head of San Fernando Valley, filling old channels and eroding new ones and, on the flatter parts of the valley, the water spreads out to assemble again in a single well-defined channel at Los Angeles, where the river breaks through a range of hills that separates the San Fernando and the San Gabriel Valleys from a broad coastal plain. The floods are then discharged beyond this range of hills on the coastal plain which has been built up, in the course of ages, by the deposit of river silt. On this last lap to the ocean, it is not surprising to find that the river has many times changed its course and has changed also the point at which it has delivered its water into the ocean. Its mouth has shifted between points thirty miles apart. The coastal plain, except along its inland margin at the base of the outlying range of hills previously mentioned, has a flat gradient to the ocean. The river channel across this plain is shallow and unstable, and each recurring flood may mark out a new course to some outfall point miles away from where it had been discharging. During flood stages, the Los Angeles River, together with the San Gabriel, menaces more than 300 sq. miles of the area of Los Angeles County.

This brief description of the Los Angeles River, largely from data assembled by J. B. Lippincott, M. Am. Soc. C. E., applies also to the San Gabriel and the Santa Ana and in a somewhat less pronounced manner to the San Diego River.

When it is recalled that distinctive floods occur about once in nine or ten years, and that, in the intervals, the broad sand washes in the upper valley invite cultivation, it will be seen that these sandy areas could readily be regarded and were treated as areas over which waters ran wild, and their ownership passed into private hands. Old channels and submersible areas have become highly improved farms and are flanked with towns and cities and valuable improvements. In such circumstances, it is not surprising to find the damage done by the floods of the two rivers in 1914, for example, to have been estimated by Mr. Lippincott at more than $7 500 000, and the incidental

depreciation of property values is given by him as possibly $2 500 000 more. In addition, there was great damage to Los Angeles and Long Beach Harbors into which the rivers deposited a large quantity of sand and silt.

In solving the flood problem of Los Angeles County, provision must be made for reducing the flood flow of the Los Angeles and San Gabriel Rivers from their present maximum discharges of about 35 000 and 25 000 sec-ft., respectively, if any material reduction is possible, by storage and by works for spreading the flood flow over broad areas of the upper parts of their previous débris cones and then confining the flood to definite channels with revetted or concrete-faced banks. This work will include a permanent diversion of the flood waters of both rivers from the Harbor of San Pedro (Los Angeles).

The work is being carried out by a district organized under State law. This district is co-extensive with Los Angeles County, and its affairs are managed by a Flood Control Commission. About $5 000 000 has already been expended on this project under the direction of Mr. J. W. Reagan, the County Engineer and Chief Engineer of the Flood Control District. So far most of the work has been on the valley part of the rivers, the heavier work in the mountains being deferred on account of the relatively high cost of providing reservoirs for holding back flood waters. It is reported that of the ten or more dams, which are to be constructed to hold back flood waters, one—the Devils Gate Dam—is nearing completion, and ground has been broken for a second, the Pacoima Canyon Dam, the estimated cost of which is $1 500 000. Two other dams are to be undertaken within the year.

For the main canyon of the San Gabriel River and the Tejunga Wash in the drainage basin of the Los Angeles River, dams are discussed (although they may not yet have been definitely incorporated as project features), which would cost about $15 000 000 and $20 000 000, respectively.

In the official report on the proposed project by Mr. Reagan, submitted in January, 1917, to the Board of Supervisors of Los Angeles County, the required work is referred to as follows:

"The work resolves itself into four parts: First, the construction of both large and small dams in the mountainous areas; second, the protection of the banks of the smaller streams together with spreading and storing of waters of these streams for beneficial use; third, the straightening and rectification through river training and bank protection of the major streams; and, fourth, protection to the harbors and shipping interests."

Then follows a brief enumeration of the principal project features and a statement to the effect that training walls are to be built so that the power of the rivers for good may be utilized in governing and straightening their present tortuous channels:

"These training walls will consist of a double row of piling about 5 ft. apart, on the up-stream face of which will be placed wire fencing, and the space between the piling filled with brush and rocks. At the especially dangerous points up and down the streams, bank protection will be used, in order to confine these waters within the single channel, and to prevent the disastrous wanderings of these streams across the fertile valleys between the mountains and the sea. In general, this bank protection will consist of a double row of

piling, or possibly a single row of piling, faced with barbed wire or hog wire, and the space between the two rows of piling, or where the bank is steep, between the single row of piling and the cut bank, filled with brush and weighted down with stones. In all instances, the growth of willows and all trees with a good, deep, firm root system will be encouraged along the banks and behind and in and among this bank protection. On the detritus cone of the San Gabriel River above El Monte there will be excavated a channel 300 to 400 ft. wide and about 4 ft. deep. The material from this excavation will be placed in levees on either side of the stream at distances varying from 600 ft. to ½ mile, the area between the minor channel and the levees to act as a spreading ground for the waters, that they may be absorbed into underground storage for beneficial use."

A dike is proposed for the diversion of flood waters from the Harbors of Los Angeles and Long Beach.

The Control of Floods at Stockton, Calif.—The Calaveras River has been cited as an example of the second type. The City of Stockton, Calif., lies in the heart of the area, which was subject to frequent submersion by the flood waters of Calaveras River. This river is a small stream with 491 sq. miles of low mountain water-shed and is practically dry in the summer and fall. Under natural conditions, the river, near the point where it reaches the easterly margin of the San Joaquin Valley, spilled its floods over its banks and these waters flowed westerly, following natural swales and depressions, to an outfall in the swamp-land areas westerly from Stockton. These waters had cut channels which, in their lower reaches, were of large capacity, but which, in many cases, "fingered" out to mere swales at their heads some distance east from Stockton. There was a junction of several of these high-water channels in Stockton, forming Mormon and Stockton Sloughs, the lower reaches of which are at sea level and have always been navigable. Because the annually recurring high waters brought down much silt which became an obstruction to navigation in the Stockton Channel and increased the maintenance charges against this waterway, the Federal Government undertook the construction of a diverting canal, the right of way and the general plan of which were provided by the City of Stockton. This diverting canal was given an oblique position across the natural slope of the country, and the excavated material was deposited on its westerly or down-stream bank. Its original capacity was about 7 000 sec-ft. The flood flow to be diverted is four or five times this quantity; consequently, this canal, although affording protection to lands at the west, has had little, if any, effect in reducing the inundation of lands to the east. It is even claimed by some that matters have been made worse instead of better, particularly as the canal does not appear to have sufficient grade to give the water a scouring velocity and silt deposits are reducing its capacity.

It is known that, in the mountains, there are reservoir sites of ample capacity to reduce the flood flow so that it can readily be conducted to its outfall into the San Joaquin River in existing or slightly modified channels. Obviously, reservoir control of the floods should here be made a project feature.

The Flood Problem at Tulare Lake.—The Tulare Lake region and the Salton Basin have been referred to as illustrative of projects of the fourth type. With Tulare Lake, an area about 750 to 800 sq. miles in extent comes into consideration. After the great flood year of 1861-62 this lake reached a very

high stage. It fell somewhat in the succeeding years, but again rose in 1867-68 to about the former level, which is generally accepted as its highest known stage. A gradual recession of the lake water has taken place since and there has been little or no northward outflow from the lake since 1876 or 1877. In 1898, the lake went dry and has been dry again in a number of seasons since 1904. Much of the land laid bare by the receding waters is very fertile, and farming has become quite extensive and profitable. The risk of a recurrence of high stages in the lake has been considered to be so slight that permanent improvements have been built as though a return of such wet conditions as are known to have occurred within the memory of man, would never happen again. Railroad lines and towns are located on land that at one time was well within the lake.

Tributary to this depressed area are the water-sheds of the Kern, Tule and Kaweah Rivers and, partly or periodically, Kings River, together with a number of lesser drainages and quite an extent of Coast Range hills on which, however, the rainfall has always been very light.

The barrier across the "thalweg" of the San Joaquin Valley, to which is due the Tulare Lake depression, was built by Kings River. If unrestrained by levees this river would send part of its flood flow south into the lake and part of it north to join the waters of the San Joaquin River. Regardless of what disposition is made of the discharge of Kings River, the flood menace to the Tulare Basin will remain. No adequate provision has been made for the interception and by-passing of the flood waters from the other rivers. All these streams are allowed to reach the lowest depression, and the attempt has been made to hold the water in check as it rises under the influence of rains and melting snows by means of concentric levees. In seasons of light rainfall, all the levees may hold, but in flood years one line of levee after another breaks, and the crops of a year or two on much of the lake bed may be lost. The greatest safety lies well up toward the old high-water line, but, unfortunately, these lands, as a rule, are the least fertile.

The conviction seems to be quite general that natural conditions, due mainly to the extensive use of water for irrigation, have been changed so that Tulare Lake will never again rise to its one-time high stages, and consolation is found by some in the fact that since 1889-90 there has been no season in which the rainfall approached this region's probable maximum of twice the normal. The unwelcome truth should be recognized, however, that irrigation, when the next very wet year comes, will not materially reduce the volume of flow into Tulare Lake, and there is no sound basis to the opinion that the climate has changed and that there will be no more extremely wet years. On the northeastern margin of the lake, as it was in the fall of 1882—about 20 ft. below extreme high-water mark—the speaker sketched a group of willow stumps, one hundred or more in number, some of which were 4 ft. in diameter. It would not have been possible for trees to have attained that growth if the lake had not been at a low stage for many years at some time preceding 1853, its history being known since that date. Indian tradition confirms this, referring to a time when the lake had contracted to two small ponds, with dry land between. This period of low water must have been followed by a series

of years when the lake was at a moderate elevation. The trees died, and the wood above water decayed, leaving the jagged ends of their stumps from 3 to 4 ft. above the surface of the ground. These stumps which, no doubt, have long ago succumbed to farming operations, were located on the south bank of the Mussel Slough, one of the original high-water branches of Kings River.

There is, therefore, no comprehensive plan for the permanent reclamation of Tulare Lake lands, and not much is likely to be done in securing such a plan until a disastrous flood emphasizes the menace.

The Flood Control Problem of Lower Colorado River.—The Salton Basin, of which the southern part is known as Imperial Valley, was, at certain prehistoric times, the outfall point of Colorado River. This basin is the depression below sea level, which, in the course of ages, has been cut off from the upper or northern end of the Gulf of Lower California. At one time the Gulf extended to and beyond Indio, Calif., a station in Coachella Valley on the Southern Pacific Railroad. The silt delivered by the Colorado River into the Gulf has built up a broad delta cone that has its apex near Yuma, Ariz., at an elevation of about 120 ft. above sea level, and that extends, with a broad, flat crest, across the valley in a southwesterly direction, about 50 miles to the Cocopah Mountains.

A sediment ridge, flat to the eye, has thus been built, that separates the Salton Basin from the Gulf. The lowest point of this ridge is about 35 ft. above sea level and it is at this elevation that an old beach line is readily traceable around the Salton Basin. About 2 000 sq. miles of the Imperial and Coachella Valleys lie below this old beach line. The lowest point of the basin is about 287 ft. below sea level, and all the cultivated areas in the valleys are below sea level.

Evidence is unmistakable that, in prehistoric times, the Colorado River has swung back and forth on its delta cone, discharging for a time into the Salton Basin and, again, into the Gulf, just as the Amu Darya, a river of Asia—the Oxus of ancient history—periodically flows into the Aral Sea and, again, into the Caspian Sea.

Due to early explorations of the Spaniards, it is known that, for 500 years, and probably much longer, the Colorado River has held to its course into the Gulf of California, except a little more than a year (1905 to 1907), during which it took a course to the north and filled the Salton Basin to a depth of 80 ft.

Just north of the point where the southern boundary of California reaches the river, water has been diverted from the Colorado River, during the last 25 years, for the irrigation of lands in the Imperial Valley. A canal of large capacity was required and the erosive action of the water was the main agency of first construction. In later years, dredges have been in use in bettering the alignment of the canal and in building up its banks. The summer flow of this canal is about 6 000 sec-ft. The canal takes a course through Mexico, this course being made necessary by topographic features. The area under irrigation with water from this canal may be given, in round numbers, as 420 000 acres in the Imperial Valley, California, and 150 000 acres in Mexico.

The silt carried by the Colorado River amounts to about 0.8% by weight or about 112 000 acre-ft. of compacted material per year. The banks of the river in their natural condition were densely overgrown with cottonwood and willow trees, weeds, and grass, so that the annual overbank flow, in the delta reaches of the river, was obstructed and had no tendency to erode the ground and form pronounced high-water channels until it was at some distance from the main stream. The permanency of the river on its original course was thus fairly well assured. An artificial channel so concentrated the outgoing water that it commenced to cut a channel. When this was once started, it could not be stopped, and in 1905 a small dredger cut, made in 1904, became the main river channel, and for a year the river poured its water into Salton Basin. With great difficulty and at large expense, operating on Mexican territory, the river was turned back into its natural channel in December, 1906, by the Imperial Irrigation District, only to break out again a few weeks later. It was then successfully turned back through the agency of the Southern Pacific Company. By this time, the whole aspect of the delta region had changed. Brush and grass had died and fires had cleared the ground so that thereafter overbank flow was less impeded than it had been previously. In 1909, the inevitable happened; the river broke through its west bank, in Mexico, about opposite the southern boundary line of Arizona, and appropriated and enlarged the overflow channel known as the Rio Abejas, or Bee River, in which it flowed westerly into Volcano Lake and thence in various channels and across country toward the south, with its outfall into the so-called Hardy Colorado.

It was necessary to build a levee just north of Volcano Lake to keep the water from taking a northerly course. Under natural conditions, outlets from this lake carried the water as well to the north as to the south. A low levee had been constructed there, in 1908, as the lake had already commenced to show its tendency to overflow the low, flat bank lands. The silt and drift which the Colorado River has now been unloading in the Volcano Lake region, have warped this area and have brought the flood-plain up at an average rate of practically 1 ft. per year. Levee building has kept pace with this rise, so that at present the Volcano Lake levee has a height of about 14 ft., a railroad track on its top, and its southerly or water face is heavily rip-rapped. Much of the material of which this levee is built was hauled in by train, because the western 8 or 10 miles of levee rests on ground too alkaline for use in levee building.

About $5 000 000 has been expended on this flood-control work, this sum having been contributed mainly by the Imperial Irrigation District of California, but expended in Mexico.

Desultory attempts are now being made to coax the river into a location more to the south of its present course, but even if these attempts should be successful, or partly so, they will not solve the flood problem of the river. There is only one course to be taken; the river must be placed on a direct course to the Gulf, not necessarily by way of the old channel, which is tortuous and lacks capacity, but on some location fairly parallel thereto. Then, as a matter of equal importance, the number of floods and particularly the long sustained summer high stages of the river should be reduced by the construc-

tion of a reservoir of large capacity somewhere on the lower river. The Boulder Canyon site has been suggested for this purpose, and studies of the feasibility of a high dam in that canyon have been made by the U. S. Reclamation Service.

The Boulder Canyon Dam site is just above the point where the Colorado River makes its abrupt turn from a westerly to a southerly course and is 3 or 4 miles below the mouth of the Virgin River. The canyon is reported as about 250 ft. wide for a distance of ½ mile. The sides of the gorge are steep, and the rock is granite. The project for storage at this site, as now favored by the U. S. Reclamation Service, involves the construction of a dam that would be about 550 ft. in height above the present low-water surface of the river. The storage capacity of the reservoir created by such a dam would be more than 25 000 000 acre-ft. The annual discharge of Colorado River at this point ranges from about 7 000 000 to 22 000 000 acre-ft., and the normal annual discharge of the river is about 15 000 000 acre-ft. A large part of the storage space would be in the lower valley of the Virgin River. The water of a full reservoir would extend up stream to the lower end of the Grand Canyon. The reservoir could be manipulated so that it would eliminate the lower river flood menace from the up-river high stages. It would regulate the flow of the river for irrigation purposes and would justify the installation of a power plant with an output capacity of about 700 000 h. p.

This reservoir would completely remove the flood menace to the Colorado River lands at Palo Verde and at other points above the mouth of the Gila. It would also prevent all extreme flood stages below the Gila, except those of infrequent occurrence caused by the Gila itself. The Boulder Canyon Reservoir, together with the outfall correction into the Gulf of California, would adequately solve the flood-control problem of the Colorado River.

The cost of providing a reservoir at the Boulder Canyon site is generally given as about $50 000 000. The agency which should carry out the regulation of the flow of the Lower Colorado River in the interest of irrigation, for the development of power and for flood control, is the Federal Government, which is the only agency that can speedily carry out the rectification of the alignment of the river in Mexico. There should be at once some understanding reached with Mexico, under which the United States will be permitted to do this work and to maintain any newly established outfall channel, and this understanding might well be coupled with some arrangement for a delivery to Mexico of some of the water to be stored at Boulder Canyon, subject, however, to a proper adjustment of the costs of the work according to the benefits conferred.

FLOOD CONTROL IN THE MIAMI VALLEY, OHIO

By Charles H. Paul,* M. Am. Soc. C. E.

The flood of March, 1913, was the greatest ever recorded in the Miami Valley. Large sections of the business and residential districts of Dayton and Hamilton, Ohio, were inundated to depths of 10 to 12 ft. At Dayton, the levees guarding the down-town district were overtopped 6 ft. or more, and the peak flow through the city exceeded the capacity of the river channel nearly 300 per cent. Similar conditions prevailed in other cities and towns in the Valley. The property loss was estimated at $100 000 000.

Relief committees were organized in the different cities immediately after the flood and plans for the prevention of future floods began to be formulated. Each community worked independently at first, the thought being that the desired results could be accomplished by channel enlargement. Soon after engineering study was begun, however, it became apparent: First, that channel enlargement alone, to the extent required, was not practicable; and, second, that the people of one city, alone, could not adequately protect themselves, and that it was a job for the people of the whole Valley to undertake as a unit. A combination of channel improvement and retarding basins was the final solution of the problem.

Under the Ohio laws, there was no practical way for the people of the Valley to organize as a unit, and it became necessary, therefore, to enact legislation for that purpose. The Conservancy Act of Ohio, passed in 1914, paved the way for the organization of the Miami Conservancy District, which was effected soon thereafter.

This Act provided that a complete outline of the proposed work, known as the "Official Plan", including plans, specifications, and estimates of cost, be prepared by the Directors of the District and submitted to the Conservancy Court for approval. The Conservancy Court for the Miami District is composed of one Common Pleas Judge from each of the nine counties affected. Immediately after the organization of the District, work was begun on the preparation of the Official Plan, and a large engineering force was employed for more than a year getting it ready to be submitted to the Court. The case was then set for hearing, at which any interested person could appear and make objection to the plan as a whole, or suggest changes in any particular. Some opposition had developed, particularly among the owners of lands that would be required for the retarding basins, and in some communities, where there was a feeling that local treatment other than that set forth in the Official Plan, would be more economical. This resulted in a thorough scrutiny of the Plan during the hearing, and it was approved by the Court without any material changes.

The next step was an appraisal of damages or benefits to property affected by the proposed construction. A Board of Appraisers, appointed by the Court, prepared an appraisal roll of damages and benefits, which was presented

* Chf. Engr., The Miami Conservancy Dist., Dayton, Ohio.

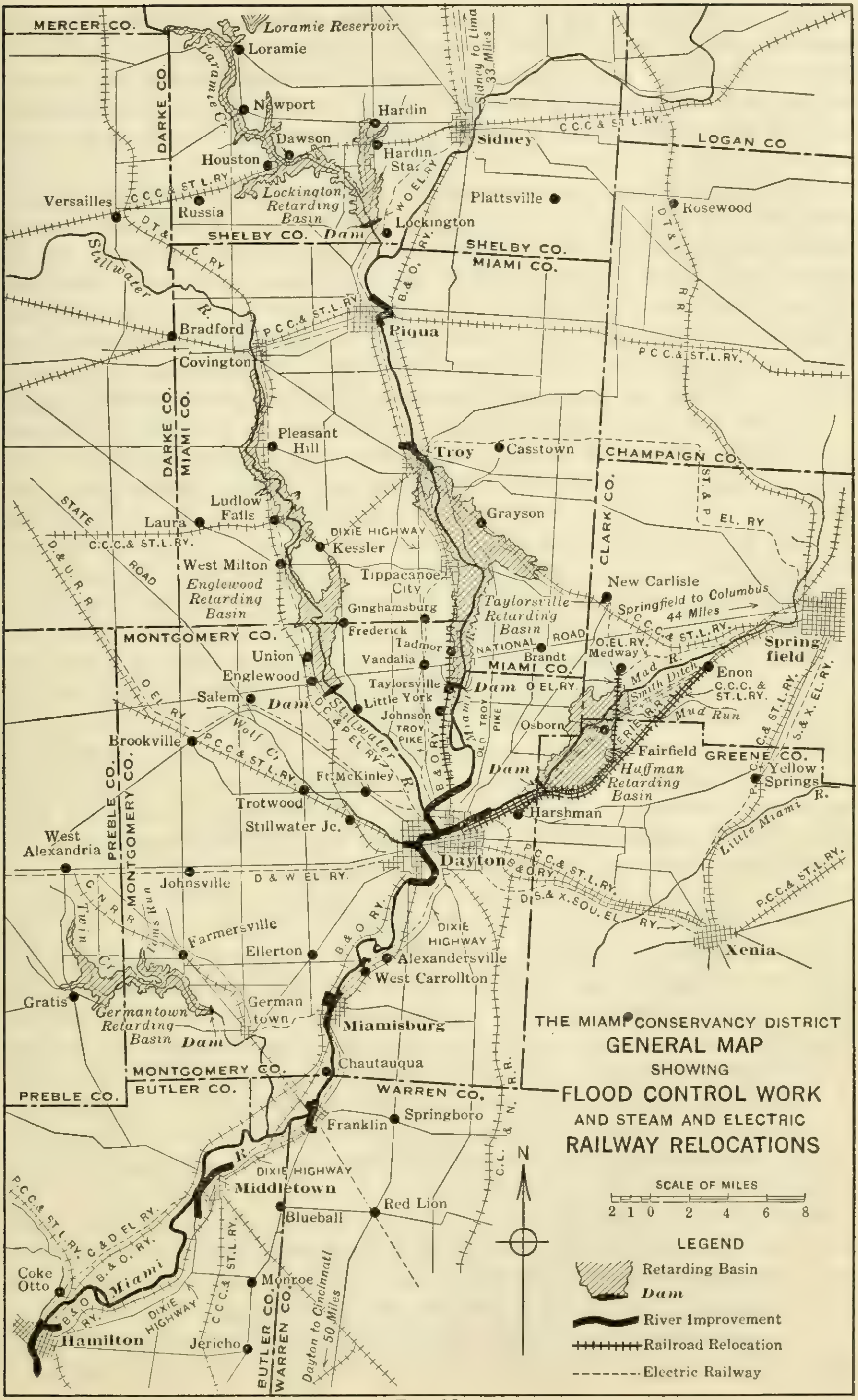
THE MIAMI CONSERVANCY DISTRICT
GENERAL MAP
SHOWING
FLOOD CONTROL WORK
AND STEAM AND ELECTRIC
RAILWAY RELOCATIONS
SCALE OF MILES
2 1 0 2 4 6 8
LEGEND
Retarding Basin
Dam
River Improvement
Railroad Relocation
Electric Railway
Loramie Reservoir
Loramie
Newport
Hardin
Dawson
Houston
Hardin Sta.
Sidney
Sidney to Lima 33 Miles
LOGAN CO
Versailles
Russia
Lockington Retarding Basin
Lockington
Dam
Plattsville
Rosewood
SHELBY CO.
MIAMI CO.
MERCER CO.
DARKE CO.
Stillwater R.
Bradford
Covington
Piqua
P.C.C.& ST.L.RY.
C.C.C.& ST.L.RY.
Pleasant Hill
Troy
Casstown
CHAMPAIGN CO.
Ludlow Falls
Laura
Grayson
Kessler
DIXIE HIGHWAY
West Milton
Englewood Retarding Basin
Tippecanoe City
Ginghamsburg
Taylorsville Retarding Basin
New Carlisle
Springfield to Columbus 44 Miles
CLARK CO.
Springfield
MONTGOMERY CO.
Frederick
Tadmor
Vandalia
Union
Englewood
NATIONAL ROAD
Brandt
Medway
Enon
Taylorsville
Little York
Johnson
Salem
Brookville
Osborn
Fairfield
Huffman Retarding Basin
GREENE CO.
Yellow Springs
Ft. McKinley
Trotwood
Stillwater Jc.
Harshman
Little Miami R.
West Alexandria
PREBLE CO.
Dayton
Johnsville
D & W EL RY.
Xenia
Farmersville
Ellerton
Alexandersville
West Carrollton
Gratis
Germantown Retarding Basin
Germantown
Miamisburg
Chautauqua
BUTLER CO.
WARREN CO.
Franklin
Springboro
Middletown
Blueball
Red Lion
Coke Otto
Monroe
Hamilton
Jericho
Dayton to Cincinnati 50 Miles

FIG. 32.

to the Conservancy Court for approval. Any property owner who was not satisfied with the award of the appraisers had the opportunity of being heard by the Court. The Roll was approved with so few exceptions that the security for bonds, as represented by uncontested appraisals, was ample to justify proceeding with the financing of the project and preparing for the construction of the works.

Fig. 32 shows three main branches of the river coming together at Dayton. From west to east, they are the Stillwater, Miami, and Mad Rivers, flowing south under the name of the Miami. Wolf Creek joins the Miami also at Dayton, just below the junction of the three main tributaries. Loramie Creek flows into the Miami at the upper end of the Valley, just above Piqua. Twin Creek joins the main river between Franklin and Middletown, and Four-Mile Creek comes in just above Hamilton. The drainage area above Hamilton is 3 600 sq. miles, and that above Dayton comprises 2 600 sq. miles.

The Miami Conservancy Plan, as finally adopted, provides for channel improvement through all the cities and towns affected by floods, to the extent that is economically feasible, supplemented by retarding basins which will hold back the crest of the flood, by restricting the flow through the dams and backing up the surplus water temporarily, in the basins. The outlets through the dams are not controlled by gates, but are designed of such size that their combined discharge, under maximum head (full basin), will not overtax the capacity of the improved river channels through the cities below. Provision is made for a maximum flood 40% greater than the 1913 flood. It is believed that this maximum is in excess of any flood that can occur in this locality. Channel improvement is provided at Piqua, Troy, Dayton, West Carrollton, Miamisburg, Franklin, Middletown and Hamilton. (See Fig. 32.) Dams which form retarding basins, are located at Lockington on Loramie Creek, at Englewood on Stillwater River, at Taylorsville on the Miami, at Huffman on Mad River, and at Germantown on Twin Creek. The cost of the work is met by special assessment against the property benefited.

Organization

It was expected to have the construction work done by contract and the principal divisions of work were advertised for bids in the fall of 1917. The United States, in the meantime, had entered the World War, labor and industrial conditions had become acute, and it was realized that no reliable contractor could, in justice to himself, make a reasonable bid on jobs as large as this, which would require 4 or 5 years to complete. Bids were opened in November, 1917, and with the exception of one bid for a small section of channel improvement, all of them were either unreasonably high or were irregular.

The Directors of the District were then faced with the postponing of construction, or of perfecting a construction force as a District organization, purchasing equipment, and proceeding with the work. The latter course was taken and results have shown the wisdom of that decision.

The engineering forces were already well organized. A construction manager was selected and superintendents were secured for the larger features of

work (the five dams, and the channel work at Dayton and Hamilton). In the spring of 1918, enough of the construction organization and equipment had been assembled so that work could be started.

The general plan of organization for construction was to maintain, as nearly as practicable, the relationship between engineering and construction forces that would have existed on contract work. On each main feature of the work was a division engineer, with authority such as he would have had on a contract job, and a superintendent who had direct charge of the construction forces. The superintendents reported directly to the construction manager whose relation to the job in many respects was like that of a contractor. The specifications which had been prepared in anticipation of letting contracts, were followed, with such modifications as the change in organization demanded. Although responsibility for the quality of work, sufficiency of methods, rate of progress, and costs, were allocated much as they would be on contract work, there was a sense of co-partnership between the engineering and construction offices, which made for better results, more rapid progress, and lower costs, than would have been possible on an ordinary contract job.

Railroad Changes

It was necessary to re-locate 50 miles of railroad lines throughout the Miami Valley, in order to get them out of the way of the dams and retarding basins. New locations satisfactory to the railroad companies were made at the expense of the District, under the general direction of the railroad companies. The old lines then became the property of the District, the rails and the ties being salvaged.

Channel Improvement

Channel improvement is almost certain to be an economical feature of a flood-control project. Even when full protection cannot be secured by such means, there is usually much to be gained, at moderate expense, by removing bars and islands, and by deepening, widening, or straightening channels within reasonable limits. The cost of additional capacity increases relatively, until finally an economical limit is reached. In the Miami Conservancy Project, the retarding-basin control has permitted channel enlargement to be confined to moderate limits through most of the cities, except Hamilton, where a considerable widening of the channel, which had been severely encroached upon by industrial plants, was unavoidable. The work at Hamilton involved considerable property damage. (See Fig. 33.)

Three general methods of channel improvement were required: First, that in which channel excavation is the essential or most prominent feature, as at Hamilton and Dayton; second, that in which the work is confined almost entirely to levee construction, as at West Carrollton, Miamisburg, Franklin, and Middletown; and, third, a combination of these two features, as at Troy and Piqua. The situation, at Troy and at Middletown, was improved by cut-off channels and in several places by clearing out trees and other obstructions.

The standard section, Fig. 33, at Dayton and Hamilton has a low-water channel about 150 ft. wide, with flat slopes, or beaches, on either side, extending out to the toes of the levees. Where the river is straight the low-water channel is located in the center and where the channel is curved, near the outside of the bends. Having determined the channel capacity obtainable at reasonable expense, the object then was to design a standard channel section to give velocities of flow as nearly uniform as possible at any given stage, and one that will be reasonably self-maintaining. It was necessary, in some cases, to narrow the old channel in order to prevent a decrease of velocity, which would result in the formation of bars.

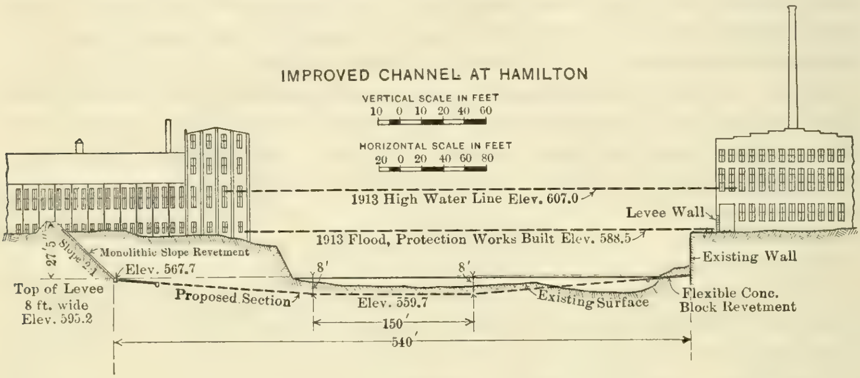

Fig. 33.

Channel improvement in most cases resulted in increased velocities of flow. To prevent erosion of banks where good sod is not sufficient, concrete revetment was used. (See Fig. 33.) On the levee slopes this revetment is of monolithic slabs, 6 in. thick, reinforced with wire mesh. These slabs are divided by expansion joints into sections of about 8 by 12 ft., the long dimension being up and down the slope. On the flatter slopes, along the toe of the levee, the revetment is a flexible mat of concrete blocks, 2 ft. long, 12 in. wide, and 5 in. thick, strung on $\frac{1}{2}$-in. galvanized wire strand. Fig. 34 shows details of this block revetment. Concrete retaining walls were used in many places, where the width of the channel is so restricted that levee slopes would require the taking of expensive properties.

Dragline excavators were used on all the larger features of the work, not only in making the channel excavation through the cities, but also in excavating for the outlet structures at the dams, and in making the borrow-pit excavation for the embankment material at the dams. The District used twenty-one of these machines varying in size from the small machine having a 30-ft. boom and a $\frac{3}{4}$-cu. yd. bucket, to the large machine with a 100-ft. boom and a 5-cu. yd. bucket. In many places, the dragline placed the material excavated from the channel directly in the levee. Where this could not be done, it was sometimes economical to move the material two or even three times to the levee.

At Dayton and Hamilton, however, the channel excavation was so much in excess of levee requirements, that a large part of the excavated material

had to be wasted. The nature of the channel at Hamilton was such that a construction track could be placed within the river out of danger from moderate floods. The waste material was loaded into 12-cu. yd. dump cars and hauled to the waste banks by 40-ton, standard gauge, dinkey locomotives.

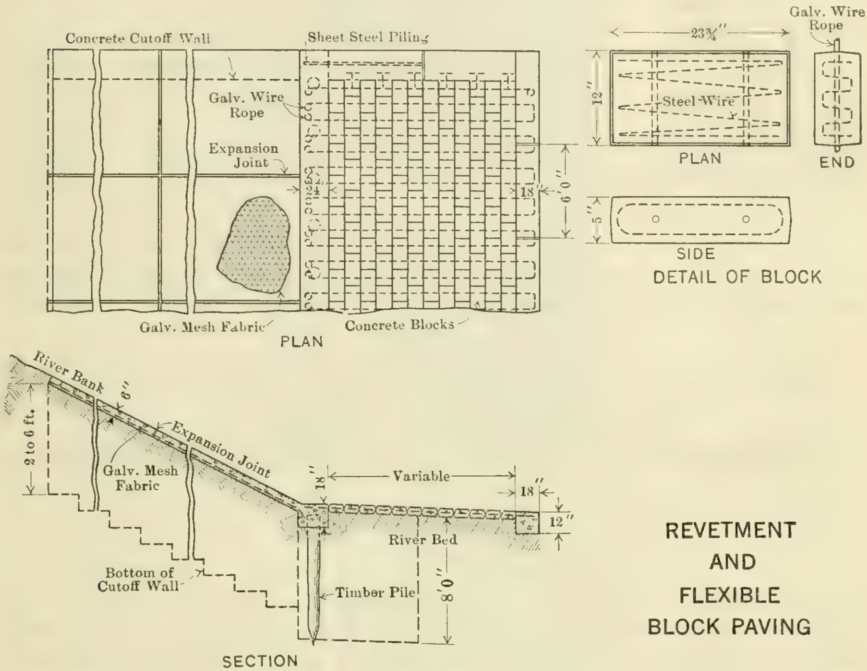

FIG. 34.

At Dayton, particularly at the upper end of the work, it was impossible to place tracks in the river bottom, that would not be exposed to the danger of even a moderate rise in the river, and extensive trestle would have been necessary. It was possible, however, to use scows for transporting a considerable part of the waste material. A part of the work was excavated by one of the large dragline machines placed on a scow. The loaded scows were towed to an unloading point near the waste bank where they were unloaded by another dragline machine, which placed the material directly into the spoil bank. At the other cities, where levee construction was one of the principal items of work, the levees were usually built by dragline machines, the necessary material being obtained from borrow-pits or from channel excavation, whichever was most practicable or economical. In a few cases, it was more economical to build sections of the levees by teams.

THE DAMS

One of the big engineering problems was the determination as to number and size of retarding basins, and the balancing of retarding basin capacities, outlet capacities through the dams, and improved river-channel capacities

through the cities. The details of this problem have been discussed in one of the Technical Reports published by the District.* The project included the construction of five dams at the locations shown in Fig. 32. The principal dimensions of the five dams are given in Table 4.

TABLE 4—SIZE OF MIAMI CONSERVANCY DAMS.

	Germantown Dam.	Englewood Dam.	Lockington Dam.	Taylorsville Dam.	Huffman Dam.
Maximum height, in feet	110	125	78	78	73
Length, in feet	1 200	4 700	6 400	3 000	3 300
Earthwork, in cubic yards	800 000	3 600 000	970 000	1 130 000	1 350 000
Concrete work, in cubic yards	17 400	26 500	32 000	48 000	37 500

Foundation conditions dictated the selection of earth dams at all the sites. Borrow-pit investigations indicated that hydraulic-fill dams would be practicable and economical, and it was decided to build at each site a hydraulic-

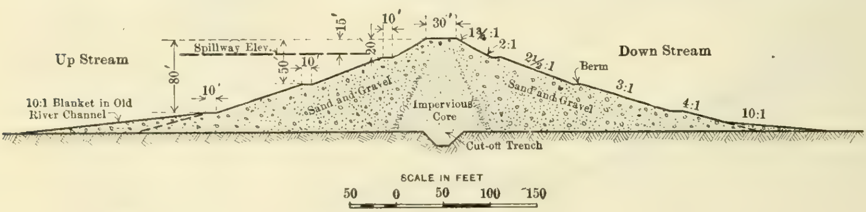

FIG. 35.

fill dam with concrete outlet structures designed to give the required control of floods. Fig. 35 shows the standard cross-section adopted for all the dams. The core width is an important feature of this design, as there are practical objections to a core that is either too wide or too narrow. The wide core, extending out under the slope material, gives scant support during the early stages of consolidation, and thus encourages the sloughing of the slope material. The narrow core permits tongues of coarse porous slope material,

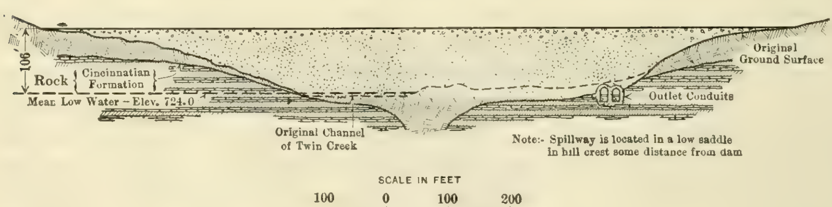

FIG. 36.

which frequently extend into or across the core zone, or far enough to meet similar encroachments from the other side, thus resulting in a porous section through the core. In the design adopted, which proved satisfactory, the theoretical core width at any point is equal to the height of dam above that point. Fig. 36 shows a longitudinal section of the axis of the Germantown

* Technical Reports, Vol. VII, "Hydraulics of the Miami Flood Control Project."

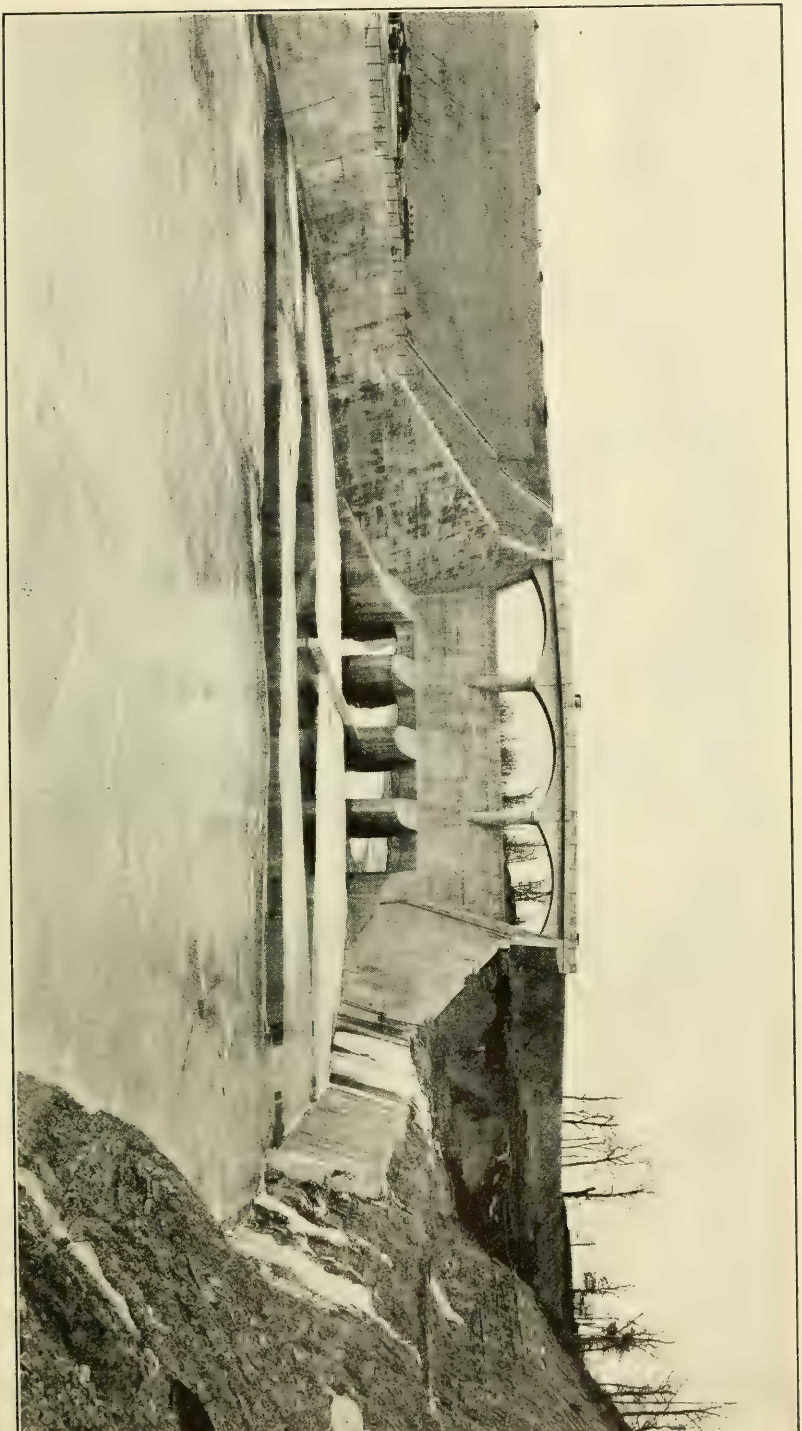

Fig. 37.—Outlet and Spillway Structure, Taylorsville Dam.

Dam, with the outlet conduits on the rock foundation at one side of the old river channel. The spillway at this dam is in a low saddle in the hill crest, some distance away.

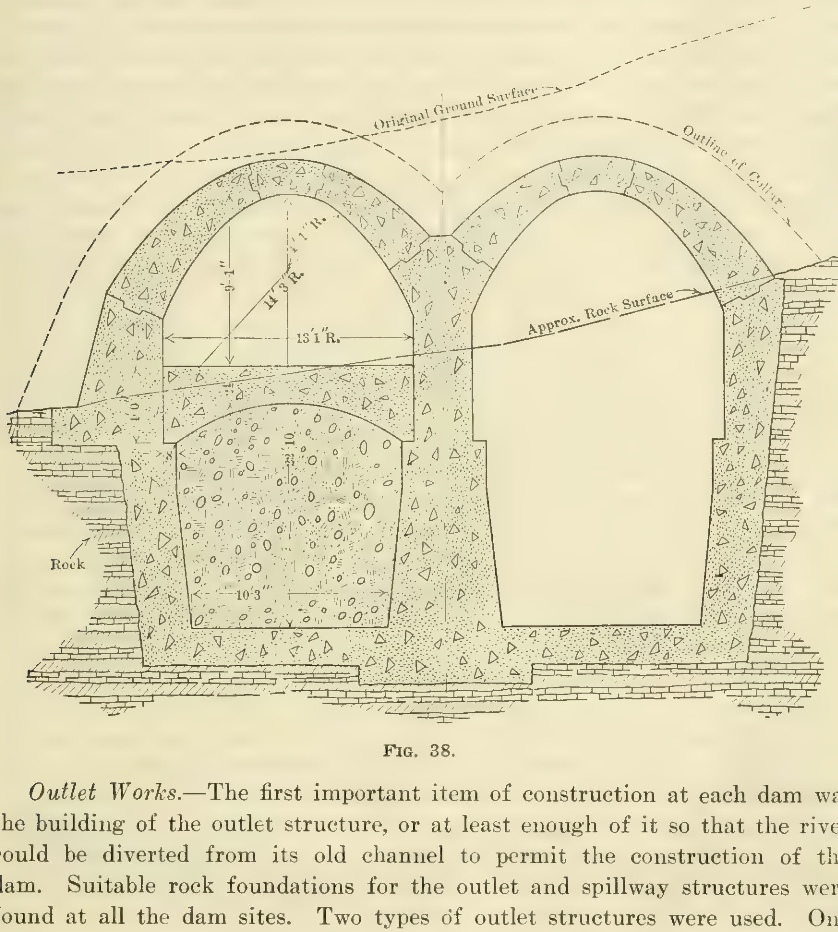

FIG. 38.

Outlet Works.—The first important item of construction at each dam was the building of the outlet structure, or at least enough of it so that the river could be diverted from its old channel to permit the construction of the dam. Suitable rock foundations for the outlet and spillway structures were found at all the dam sites. Two types of outlet structures were used. One type, which was used at three of the dams (Lockington, Taylorsville, and Huffman), was an opening through the dam formed by two retaining walls with a concrete floor between. This opening gave ample waterway for floods during the construction period. After the dam had been built to the point where there was no further danger of overtopping in case of a flood, a cross-dam was built between the two retaining walls, and through the bottom of this cross-dam, at river level, the conduits for permanent flood control were constructed. The top of the cross-dam was placed 12 to 15 ft. below the top of the dam, thus forming the spillway. Fig. 37 shows a typical structure of this type. This design has two advantages: First, no additional expense is required to obtain a waterway large enough to care for floods during construction; and, second, the conduits and spillway are combined in the same structure.

At Germantown and Englewood, however, the dams are so high that the cost of retaining walls to sustain the hydraulic-fill embankments was prohibitive, and two conduits, at the elevation of the old river bed, extending through the base of the dam, were used. In order to secure additional capacity to care for floods during construction and prevent the overtopping of uncompleted embankment, these conduits were made deeper than was required. As soon as the dam had reached a height so that there was no further danger of being overtopped by floods, the bottoms of these conduits were filled in and floored over, leaving the conduit opening of the size required for permanent flood control. Fig. 38 shows some of the details of this type of conduit, particularly the additional capacity available for use during the construction period, and the method of reducing the size of opening to that needed for permanent flood control. It also shows the location of construction joints in the conduit arches, the interesting feature of which is the pair of joints near the crown of the arch. The "keystone" section between those two joints was poured after the concrete on either side had set, and this method proved to be effective in preventing cracks along the crown of the arch. At the two dams (Germantown and Englewood), where these conduits were used, the spillways were separate structures.

At the down-stream end of each of the outlet structures, a stilling pool was built for the purpose of dissipating the energy of this swiftly flowing water. The details of this stilling pool are shown on Fig. 39, which is a longitudinal section through the conduit and outlet structure of the Germantown Dam. Each structure is designed so that the hydraulic jump, or standing wave, will be formed on the sloping floor, where the concrete is built of sufficient thickness to withstand the action.*

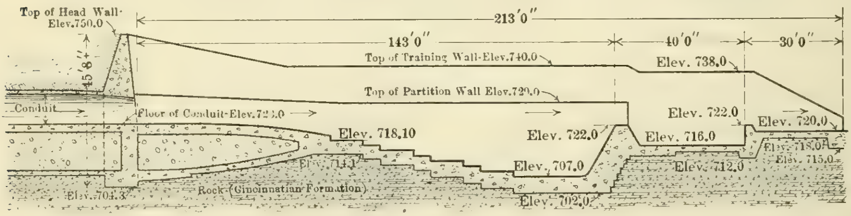

FIG. 39.

Excavation for the outlet structures was performed by dragline machines. A large part of the material had first to be loosened by blasting, care being taken not to disturb the material outside the neat lines. The vertical sides of the rock excavation were trimmed by hand to neat lines, and the concrete was placed with no outside forms below the rock surface.

At each of the dams a gravel washing and screening plant was erected for furnishing material for the outlet and spillway structures. These plants were standardized and all parts were interchangeable. Suitable gravel and

* The experiments leading up to the adoption of this design, and the theory of the hydraulic jump, are discussed in detail in Vol. III of the Technical Reports published by the District, "Theory of the Hydraulic Jump and the Backwater Curves".

sand for concrete was found near each site. The material was hauled to the plant in dump cars and dumped into a hopper at track level, from which a belt conveyor took it to the top of the plant to the screens. Wash water was delivered to the screens by a small centrifugal pump. The material was washed and separated into three sizes, sand, fine gravel, ranging in size from $\frac{1}{4}$ in. to $1\frac{1}{2}$ in., and coarse gravel graded from $1\frac{1}{2}$ to 3 in. in size. Each of these sizes passed by gravity into separate storage bins. Over-size material could be either wasted or diverted to the coarse gravel bin. In the heavy walls, it was the practice to use over-size up to about 6-in. cobbles.

A 1-yd. mixer was placed in such position that the material from each of the three bins could be fed to the charging hopper by gravity, through adjustable measuring boxes. Cement was stored in a shed near-by, and was brought to the mixing platform on small warehouse trucks as needed. The mixer discharged into side-dump cars, or bottom-dump buckets on trucks, which were hauled to the work by 3-ton narrow-gauge, gasoline locomotives. At Germantown and Englewood, where the long conduits were built, most of the concrete was chuted into place by gravity. At the other dams, and at the spillway structures at Germantown and Englewood, the concrete was placed by derricks. Collapsible sectional forms were used for the conduit construction at Englewood and Germantown. In building the large retaining walls at the other structures, movable panel forms were generally used. The concrete mix varied from about $1:1\frac{3}{4}:3\frac{1}{2}$ in conduit linings, to about $1:3:6$ in the bodies of the heavy retaining walls, the change in the mix, within the limits required, being accomplished by changing the number of sacks of cement per batch. Special care was taken to use no more than the required quantity of water per batch. The two sizes of gravel were re-mixed in the batch in such proportion as to use up practically all of each size, and this ratio between fine and coarse gravel was fixed to suit the conditions in the borrow-pit. In other words, no attempt was made to establish a theoretical combination of the fine and coarse gravel, which would have meant a considerable waste of one size or the other from time to time. There was an advantage, however, in having some fine and some coarse gravel in each batch, as this guaranteed more uniform batches than can be obtained from one bin containing all grades of gravel, and was considered sufficient justification for the separation of the gravel into two grades. The sand was carefully proportioned in the batch.

Preparation of Foundations.—The valley floor at each of the dam sites was gravel to indefinite depths, with an overburden—outside the main river channel—of clay varying in thickness from a few inches to several feet, covered with a thin layer of top soil. In preparing the foundations, all top soil and vegetable matter were removed, and roots 1 in. or more in thickness were grubbed out. A cut-off trench, deep enough to serve also as an exploration trench, was dug along the center line of the dam and was afterward filled with core material. As the dams will back up water only in times of flood, loss of water by underflow is not objectionable, and, therefore, no attempt was made to cut off all the seepage under the dams, but only to force

such seepage to travel far enough so that no erosion of embankment material and no possible damage to the structure could occur.

Although sheet-pile cut-offs were used, in most cases, across the old river beds, the principal reliance for control of seepage was placed on blankets of impervious material extending up stream from the core section of the dam. The clay overburden, up stream from the cut-off trench, was examined by means of post-hole diggers and the thin spots were reinforced by artificial "patches" of rolled material. In the old river bed, an artificial blanket of selected material was placed in layers and compacted so that before the hydraulic fill was started, a complete blanket of impervious material, several feet in thickness, covered the dam site up stream from the cut-off trench, connecting with the impervious core of the dam and extending up stream from the up-stream toe as far as necessary to give a ratio, length of seepage travel to head, of about 8 or 9 to 1.

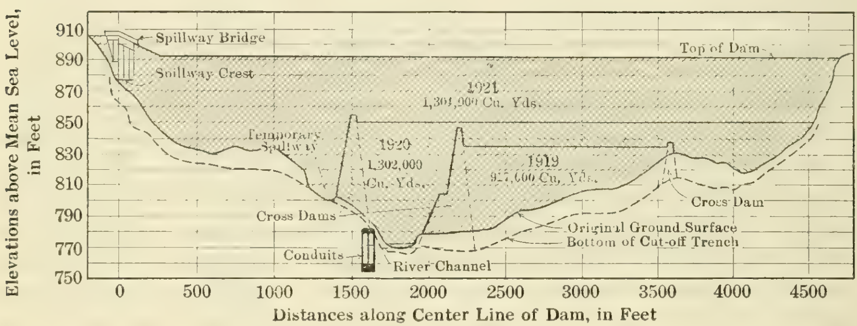

FIG. 40.

River Control During Construction.—At each of the dams, river control during construction was a serious problem, as sufficient waterway had to be maintained to provide for flood flow. The program had to be arranged so that a flood even as large as that of 1913 would not be aggravated by the construction. Although the problem of river control was somewhat different at each dam, the general principles were the same. The procedure at Englewood well illustrates the methods used and Fig. 40 shows the various steps in the construction program. While the conduits were being built on the west bank of the river, a section of the hydraulic fill containing nearly 1 000 000 cu. yd. was constructed on the east side, with a cross-dam along the river bank to hold the semi-fluid hydraulic core in place. During this period, the old river channel remained open, and was left open until the next flood season had passed. Then, another section of fill was placed, extending across the old river channel and over the conduits. Although a season's work at Englewood amounted to 1 000 000 cu. yd. or more, it was impossible to place in one season all the remaining embankment to a height sufficient to turn through the conduits a flood as great as that of 1913. It was necessary, therefore, during this second season's work on the fill, to leave a temporary spillway

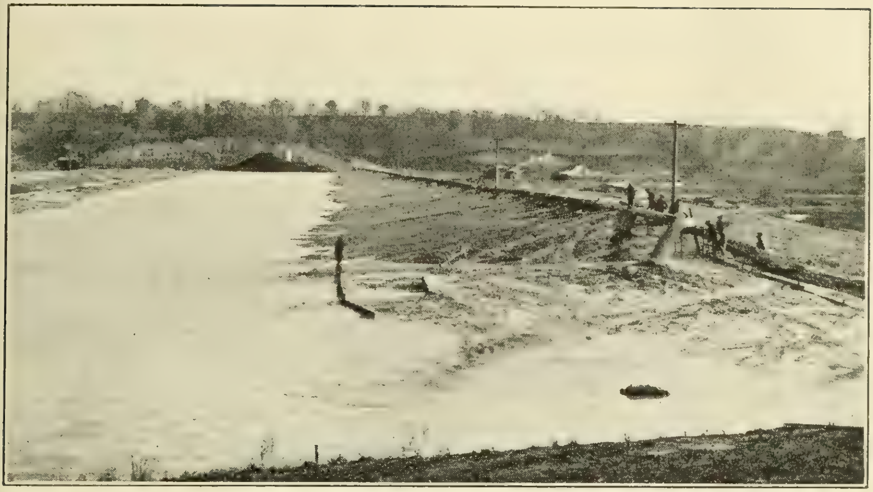

FIG. 41.—METHOD OF PLACING HYDRAULIC FILL

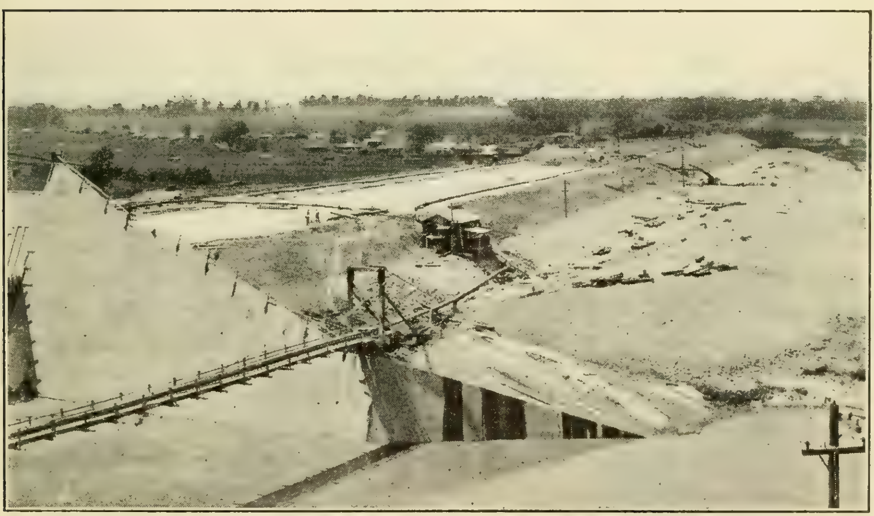

FIG. 42.—TAYLORSVILLE DAM UNDER CONSTRUCTION. LOW SECTION OF DAM IS RIVER CLOSURE SECTION.

at one side of the old river channel. The bottom of this temporary spillway, however, could be left considerably higher than the river bed, and that much was gained toward the final closure. This temporary spillway provided sufficient waterway for protection during the next flood season, and as soon as that had passed, the gap forming that spillway was closed, and it was possible to complete the dam to its full height before the next flood season occurred.

In making these closures of river channels and temporary spillways, certain critical periods had to be anticipated and provided for; for instance, after the river had been diverted, a certain amount of fill could be placed in the closure section before it reached a height at which overtopping would have any appreciable effect on flood flow. From that point, to the time an elevation had been reached sufficient to turn a big flood through the temporary outlet channels, was the most critical period during the construction of the dam, and the safety of the valley below the dams required that this period should be coincident with the low-water season in the river. As a further precaution, it was arranged not to have this stage of construction occur at more than one of the dams at the same time, and every effort was made to rush the work with all possible speed consistent with safety.

Hydraulic Fill.—The hydraulic-fill method of building dams originated in the West and was first suggested by placer mining operations. Where materials are suitable, and proper methods are used, excellent results are obtained at comparatively low cost.

At each of the sites the embankment material was pumped to the dams by 15-in. dredge pumps, as it was impossible to sluice directly from borrow-pit to embankment. In two cases, however, the borrow-pit material was broken up by hydraulic giants and sluiced to sumps, from which it was pumped into place. At the other three dams, the borrow-pit material was excavated by dragline machines, loaded into 12-cu. yd. dump cars, hauled to the dams by 40-ton standard-gauge, dinkey locomotives, and dumped into shallow bins or "hog boxes." At the "hog boxes," hydraulic giants were used to wash the material to the dredge pumps. Thus, by the time it reached its place in the dam, the borrow-pit material was thoroughly broken up and separated. The discharge pipes from the pumps deposited the material along the outer edges of the dam section, a low levee or dike along the outside slope forcing the discharge to flow toward the center where the core pool was maintained. (See Fig. 41.) The coarser of the material consisting of cobbles, gravel, and coarse sand remained in the outer parts of the embankment, and the fine sand, clay, and silt flowed to the center with the water and settled through the core pool to form the impervious core. Fig 42 shows another view of one of the dams under construction.

The fill was built in layers, varying in thickness from 2 to 4 ft. at the different dams. Each lift was staked out in advance, and efforts were made to keep the shore line of the core pool straight and even as each layer was carried forward. (See Fig. 41.) Different methods were used for keeping the outside edge of the slope high enough to turn the flow from the dredge pipe toward the central pool. At one dam, this was done by hand; at another,

teams were used. At the other dams, where 3 or 4-ft. lifts were common, a small dragline machine was used to build up the levees ahead of the fill. Near the end of the work, at one of the dams, this was done by a small back-filling machine with caterpillar traction. This was the most effective of any of the methods used.

The control of the hydraulic-fill cores, both as to gradation of material and rate of consolidation was given careful attention. During construction, the composition of the core may be controlled within certain limits by the selection or choice of borrow-pit material, by wasting the finest of the material from the core, in case a surplus of fines is present, or by securing additional clay from auxiliary borrow-pits, where the main borrow-pits are deficient in fines. There are various methods of controlling core width and of studying the character of core material and rates of consolidation. A description of the core studies at the Conservancy dams has been presented to the Society by the speaker.*

Several kinds of dredge pumps were tested during the early stages of the work. Those that gave the best results had shells of either white iron or manganese steel, with manganese runners and removable manganese shoes on the runner blades. These removable shoes not only doubled or trebled the life of the runner, but also permitted an easy change in effective length of blades, to meet the requirements of increased head as the embankments were raised in height. Special electric-welded dredge pipe of high carbon steel was used with satisfactory results. In service tests, the life of this pipe exceeded that of the old style standard dredge pipe, by 200 to 300 per cent.

Progress and Results.—The rate of progress of hydraulic fill at some of the dams is thought to be worthy of mention. At Germantown, with one dragline machine in the borrow-pit and one dredge pump, an average month's work was about 60 000 to 70 000 cu. yd. During one month the output reached 91 500 cu. yd. At Huffman, with about the same equipment, the rate of progress was about the same. At Taylorsville, with four giants in the borrow-pits and two dredge pumps, the highest monthly estimate reached 107 000 cu. yd. At Englewood, with three dragline machines in the borrow-pit and two dredge pumps, the monthly record of hydraulic fill often reached 150 000 cu. yd., and one month it was 180 000 cu. yd. In the fall of 1917, a progress schedule was set that provided for completion of the five dams at what was believed to be the earliest date consistent with economy. In spite of the necessity for organization of forces and purchase of equipment for construction by the District, delays due to war conditions, priority regulations in employment, purchases, and shipment, car shortage, and generally unfavorable conditions, all the dams were completed, ready to handle a flood, a year ahead of the original schedule.

Although the work is now in such shape that the Valley is protected against a flood like that of 1913, there is still much work to be done, especially on some of the larger of the channel improvement work. The construction will be

* "Core Studies in the Hydraulic-Fill Dams of the Miami Conservancy District", *Proceedings*, Am. Soc. C. E., March, 1922, p. 453.

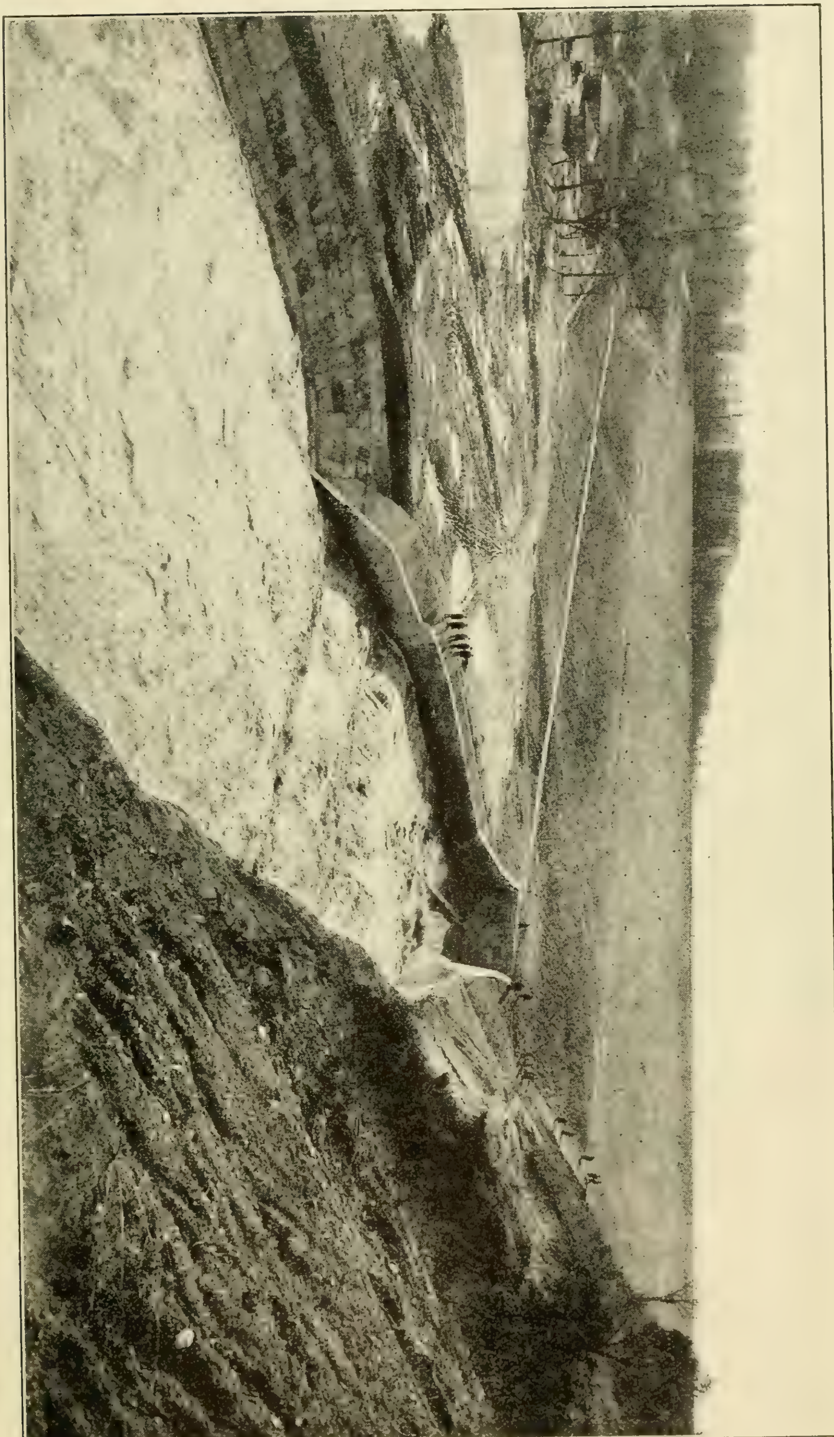

FIG. 43.—GERMANTOWN DAM, COMPLETED, SHOWING HYDRAULIC JUMP IN ACTION DURING SMALL FLOOD.

completed during 1922. The principal quantities involved in the whole work are as follows:

Public Service Relocations:		
Earth and rock	2 500 000	cu. yd.
Concrete	30 000	" "
Railroad lines	55	miles
Flood-Control Works:		
Earth and rock	19 000 000	cu. yd.
Concrete	250 000	" "

No large floods have occurred since the completion of any of the dams, but two of them have already been tested to the extent of holding back water in the basins to depths of 30 ft. or more. Fig. 43 shows one of the completed dams, with the hydraulic jump in action during a moderate flood.

DISCUSSION ON FLOOD PROBLEMS

By Messrs. Morris Knowles, Harrison P. Eddy, J. Albert Holmes, D. W. Mead, Arthur O. Ridgway, J. B. Challies, George M. Lehman, W. H. Breithaupt and Adolph F. Meyer.

Morris Knowles,* M. Am. Soc. C. E.—The flood-control problem at Pittsburgh, Pa., which the speaker will discuss, is concerned with four States, as far as inaugurating the policy relates to legal or legislative entanglements. Works will be constructed in Pennsylvania, New York, Maryland, and West Virginia, and beneficial results will be felt in at least two other States and down the Ohio River to Cairo, Ill. Thus, the ultimate consummation of the plan is exceedingly difficult.

The comprehensive report of the Pittsburgh Flood Commission revealed the necessity and the extent of the problem, the involved relationship of the many factors, and the need of the correlation of many jurisdictions. Education is necessary, and the project has progressed sufficiently to show the requirements and the methods and machinery which may be established to carry on this work. The Pittsburgh engineers, civic groups, and municipal authorities realize the extent and breadth of the problem, and the danger of an inadequate solution.

Moreover, much has been accomplished; there has been a review by the United States engineers and a recommendation that surveys and plans be made by the War Department, for the purpose of securing flood protection and prevention in certain rivers, and those tributary at Pittsburgh are among such streams. The State of Pennsylvania, in 1919, appropriated $25 000 as its contribution for such surveys and plans, with the idea and request that the United States Government should direct the work through its Army Engineers and should appropriate money for this purpose. A bill, known as H. R. 5 357, 67th Congress, First Session, provides for $50 000, to conduct this work and to co-operate with the State of Pennsylvania. It is expected that this bill will pass during the 67th Congress.

Great areas at the head-waters of the Allegheny and Monongahela Rivers and their tributaries have already been acquired by the United States for forest reservations, and $50 000 has been expended for this purpose, on the Allegheny water-shed, in Northwestern Pennsylvania. The latter has just been made possible by the passage, by the State of Pennsylvania, of an Act enabling the United States Government to acquire such property within the State. The National Forest Commission has recommended the purchase of 500 000 acres in Northwestern Pennsylvania, and about 1 000 000 acres have been secured at the head-waters of the Youghiogheny and Cheat Rivers in Maryland and West Virginia. These areas include vast denuded lands on the upper water-sheds, where the hardwood industry was once active.

* Director, Dept. of San. Eng., Univ. of Pittsburgh, Pittsburgh, Pa.

The improvement of the wharves at Pittsburgh, including the reclamation of many acres of unused river-front, the erection of dockage facilities, and the construction of flood walls to protect low-lying areas, is now receiving attention through the efforts of Mayor William A. Magee, the United States Engineer's office at Pittsburgh, the Pittsburgh Flood Commission, the Planning Commission, and the Committees of the Metropolitan District of Pittsburgh, all acting as a unit. It is expected that, within a short time, this adequate development of the much abused river-front will be secured and, at the same time, furnish protection from ordinary floods.

The speaker wishes to call attention to the fact that this entire movement and program is only one part of the great community planning idea, namely, a development of the idea of the wisdom of utilizing the great resources of flowing and falling waters to secure the greatest good and benefits to all the people and to all activities. The Pittsburgh Flood Commission was the first to suggest (when this view was not as popular as it has since become, with a growing realization of the difficulties and breadth of the problem) that flood prevention and flood protection be combined and, with wise provision for each, many correlated questions will be solved.

There was the possibility at one time to plan for wise occupation and complete development in the river valleys, but this opportunity has been frequently misused, sometimes by a railroad, a canal, an improved river for navigation, or the location of a town or an industry, but too frequently, it has been the domination of one development and its apparent best interests, without thought of the relationship to others whereby everything could be wisely adapted to promote the greatest development of all activities. It has been realized too late that this is not adequate planning, and communities have frequently been inundated—much to their discomfort and disaster. Engineers now find the problem increasingly difficult, which is true in all cases of replanning.

However, opportunity still exists, as with the proposed wall at Pittsburgh, or the elevation of streets out of ordinary flood levels, to plan for thoroughfares, parking, boulevards, and terminal facilities. Witness the attractive river-front development at Dayton, with walls and levees, at Harrisburg, Pa., by use of concrete walls and parking, or the convenient and pleasing boulevard drive, along the Susquehanna River at Sunbury, Pa., placed on top of a river levee. Thus, through traffic need not be diverted about and around the town. Thus, too, in several river valleys not yet fully developed, the chance still exists of choosing the wisest development. This is true community or country planning.

In true and wise planning, it may be thought best to locate a railroad in one place, an improved channel in another, a reservoir on a wild land in another, forestation on another, etc., so as to obtain the most complete use and activity of land, water, and all related potentialities. The Pittsburgh Flood Commission, the City of Pittsburgh, the County of Allegheny, and the State of Pennsylvania, all unite, therefore, in agreement that there is no general, common, or single panacea to suggest, but a complete program should be studied and developed.

In harmony with this view, these interests believe that both land and waters—great facilities each—are to be developed to the greatest use. They believe that stored water may have many potential uses, and when released at proper times, under control, between well designed banks and regulated channels, affords a great blessing for the frequently denuded and inundated valleys, holding the water back at times of danger, letting it out at drier times, to the improvement of navigation, development of power, increase of water supply for various purposes, dilution and oxidation of waste products, and the general betterment of all unpleasant conditions. Furthermore, that a single solution which forgets, hinders, or hampers other developments, is unwise. It is hoped and expected, that the efforts in education and propaganda will result in that wiser development which will regard all factors and all uses and result in what is called complete community planning.

HARRISON P. EDDY,* M. AM. SOC. C. E.—One of the most important questions to be solved in any flood problem is that of the maximum flood flow for which provision must be made in the works to be designed. It may often be impracticable to provide protection against the greatest flood which must be expected at rare intervals, but, nevertheless, the greatest probable flood must be considered and the works must be made safe against serious damage under the most trying conditions, even though they do not fully protect the community against loss at such times. It may be necessary to provide spillway or waste-channel capacity for the greatest probable flood, since, in the majority of cases, failure of the dam due to inadequacy of the spillway might result in more serious disaster than would be probable from an inadequacy of stream channel.

A great many dams have been built without adequate spillway capacity; many of them were built without adequate engineering design; others, designed when comparatively little information on extreme floods was available, were given what was supposed to be adequate spillway capacity, but much less than would be provided at present. The paucity of information relating to flood flows and necessary spillway capacities in nearly all the treatises on dams, is startling. In fact, many of them make no references to the subject. The old rule, that a spillway should be capable of passing a 6-in. depth of water on the drainage area in 24 hours, has long been known to be unscientific, and, in many cases, has resulted in inadequate provision, yet it is still quoted and apparently with approval in some recent reference books. The subject has been fully discussed by F. W. Scheidenhelm, M. Am. Soc. C. E.,† and his suggestions, if generally adopted, would lead to a radical departure in the liberality of spillway design from that more or less commonly adopted in the past.

Much more liberal provision for discharging storm water is certain to be required in the future. Many existing dams will have to be modified to provide adequate spillway capacity, and some of this work is being done, noticeably in Pennsylvania, where the State Water Supply Commission is

* Cons. Engr. (Metcalf and Eddy), Boston, Mass.

† *Transactions*, Am. Soc. C. E., Vol. LXXXI (1917), p. 907.

investigating the adequacy of spillways and requiring owners to make changes where necessary.

The data on which to base a decision of the maximum flood to be expected in any given locality, are comparatively few and must be supplemented by a detailed study of rainfall and run-off records. Such data should also be checked carefully against records of excessive floods throughout the United

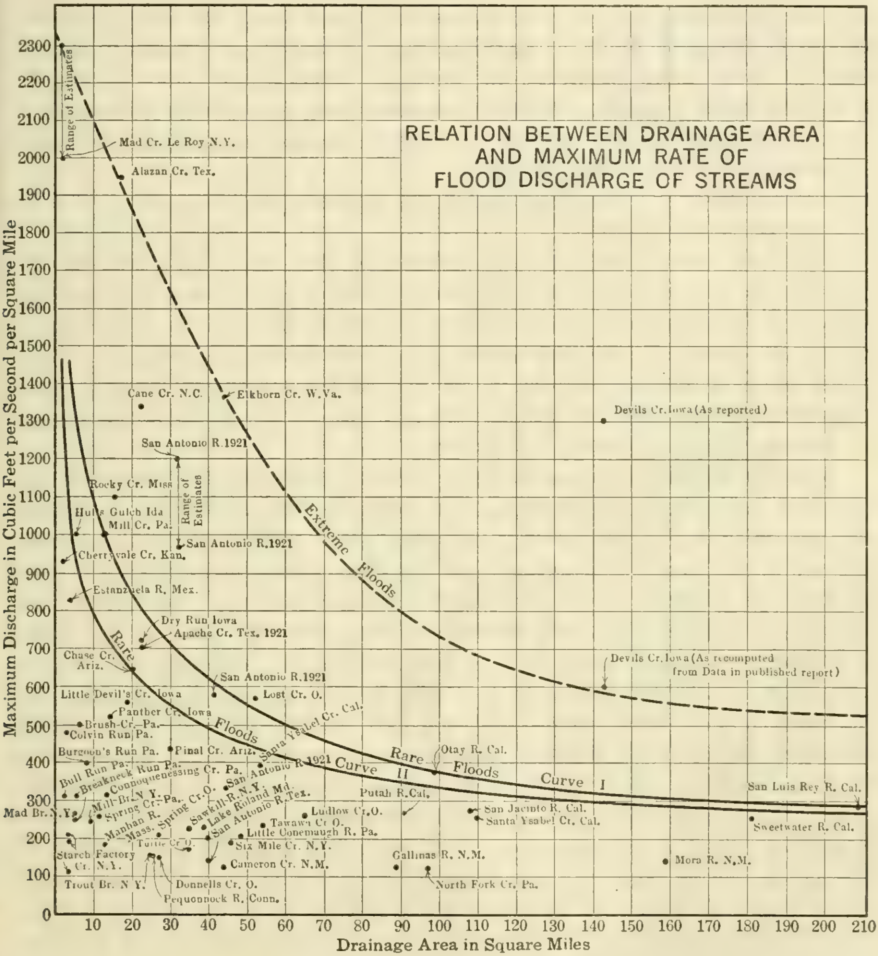

FIG. 44.

States. In view of the difference in climatic conditions, it is somewhat surprising that the relation between maximum flood discharge and extent of drainage area appears to be approximately the same through the United States, although there may be a decided difference in the frequency with which such floods occur. In spillway design the maximum discharge, rather than the frequency, would probably be the governing factor.

Records of floods of unusual magnitude, have been plotted on Fig. 44, on which three curves are shown. The upper curve represents the maximum floods of which apparently authentic records are available—floods which are probably to be classed as "acts of God". In addition to the two floods shown on this diagram support is also given to this curve by one from a much larger area—the flood of 1909 in the Santa Catarina River at Monterrey, Mexico. These flows are so great that it will probably be impracticable to make provision for protection against flooding resulting from them, but their possibility should be borne in mind, in guarding against failure of structures the collapse of which might accentuate the damage. Curve I and Curve II, Fig. 44, both intended to represent floods of rare occurrence, indicate the magnitude of the flood flows, for which provision should in general be made in structures intended to minimize flood damages.

Table 5 gives the data from which the diagram was constructed, and the sources of the information.

It is not unlikely that, as Allen Hazen, M. Am. Soc. C. E., has stated*: "It may be expected that the continuous records of gauging stations will ultimately be more useful in establishing these laws than records of destructive floods that occur now and then where there is no continuous gauging". Until much more is known, however, about the relations between frequency and magnitude it will still be necessary to rely largely on the scattered records of extreme floods, especially for spillway design.

The best method yet proposed for predicating maximum flood flows on data obtained from continuous gaugings is doubtless that of Weston E. Fuller, M. Am. Soc. C. E.† An attempt to apply Mr. Fuller's method to a stream for which the record of gaugings does not extend over a considerable period of years, is likely to be unsatisfactory; at least, that was the writer's experience in studying the flood problem of San Antonio, Tex. In the report submitted by his firm to the City of San Antonio on December 6th, 1920, is a discussion of the application of the Fuller formula to the San Antonio River, in which it was shown that, using the data on "Western Gulf of Mexico Streams", quoted in Mr. Fuller's paper previously mentioned, the largest coefficient indicated for that region is 31, which would correspond to flood-flow rates of 64 and 84 sec-ft. per sq. mile for frequencies of 100 and 1 000 years, respectively, and a drainage area of 41 sq. miles. Taking such records of the actual flow of San Antonio River as were available in 1920, but using maximum rates of flow for the largest floods instead of maximum daily average flows, the coefficient for San Antonio River was estimated as 167, 5½ times as large as was indicated by Mr. Fuller from the data available at the time his paper was prepared. Yet the application of the formula with this coefficient indicates flood flows of only 345 and 450 sec-ft. per sq. mile, for frequencies of 100 and 1 000 years, respectively. The actual rate of flow in the 1921 flood, according to an estimate made by C. Terrell Bartlett, M. Am. Soc. C. E., was 580 sec-ft. per sq. mile.

* *Proceedings*, Am. Soc. C. E., March, 1922, p. 707.

† *Transactions*, Am. Soc. C. E., Vol. LXXVII (1914), p. 607.

TABLE 5.—FLOOD FLOW OF STREAMS.

Stream and locality.	Drainage area, in square miles.	Flood flow, in cubic feet per second per square mile.	Date of flood.	References.
Mad Creek, Le Roy, N. Y.	1½	2 000 to 2 300	May 1916	*Eng. Record*, Vol. 73 (1916) p. 842.
Cherryvale Creek, Cherryvale, Kans.	2	930	(?)	*Eng. News-Record*, July 3, 1919, p. 31; *Transactions*, Am. Soc. C. E., Vol. LIV, p. 200, and Vol. LXXVII, p. 658.
Bull Run, Jeannette, Pa.	2.25	310+	July 5, 1903	Pa. Water Supply Comm. Rept., 1912, p. 50.
Colvin Run, Grindstone, Pa.	2.7	480	July 21, 1912	Pa. Water Supply Comm. Rept., 1914, p. 45.
Starch Factory Creek, New Hartford, N.Y.	3.4	108 109 190 209	March, 1903 March 25, 1904 June 21, 1905 Sept. 3-4, 1905	*Water Supply Paper 147*, p. 37; *Water Supply Paper 162*, p. 12; N. Y. State Engr. Rept., 1905, p. 690.
Estanzuela River, Monterrey, Nueva Leon, Mexico	3.5	825	Aug. 27-28, 1909	*Eng. News*, Sept. 23, 1909, p. 315.
Hulls Gulch, Boise, Idaho	5.	1 000	July 24, 1913	*Monthly Weather Review*, July, 1913.
Mad Brook, Sherburne, N. Y.	5.0	262	Sept. 3-4, 1905	*Water Supply Paper 162*, p. 12.
Breakbeck Run, Bullskin Township, Pa.	5.2	310 250	May 19, 1902 Aug. 19, 1912	Pa. Water Supply Comm. Rept., 1914, p. 47.
Brush Creek, Jeannette, Pa.	6.	500+	July 5, 1903	Pa. Water Supply Comm. Rept., 1912, p. 69.
Burgoon's Run, near Altoona, Pa.	8.1	400+	May 20, 1894	Pa. Water Supply Comm. Rept., 1912, p. 59.
Mill Brook, Edmeston, N. Y.	9.4	241	Sept. 3-4, 1905	*Water Supply Paper 162*, p. 12.
Spring Creek, Harrisburg, Pa.	11.6	238	Feb. 15, 1908	Pa. Water Supply Comm. Rept., 1910-11, p. 930.
Mill Creek, Erie, Pa.	12.9	1 000	Aug. 3, 1915	*Eng. News*, Nov. 11, 1915, p. 937.
Manhan River, Holyoke, Mass.	13.0	182	Feb. 13, 1900	Letter of James L. Tighe, M. Am. Soc. C. E., June 13, 1919.
Connoquenessing Creek, Oakland, Pa.	13.6	315	Aug. 28, 1903	Pa. Water Supply Comm. Rept., 1914, p. 48.
Panther Creek, Iowa	14.	520	June 10, 1905	*Water Supply Paper 162*, p. 26, and Meyer's "Hydrology", p. 134
Rocky Creek, near Ellisville, Miss.	15.	1 110	May 7, 1882	*Transactions*, Am. Soc. C. E., Vol. XXV, p. 116.
Alazan Creek, San Antonio, Tex.	16.9	1 950	Sept. 9, 1921	*Proceedings*, Am. Soc. C. E., Nov., 1921; *Proceedings*, Am. Soc. C. E., March, 1922.
Little Devil's Creek, Iowa	19.	560	June 10, 1905	*Water Supply Paper 162*, p. 26, and Meyer's "Hydrology", p. 134.
Chase Creek (tributary of Gila River), Arizona	20.	647	Dec. 1906	*Transactions*, Am. Soc. C. E., Vol. LXXVIII, p. 583.
Cane Creek, Bakersville, N. C.	22.	1 341	May 20, 1901	*Eng. News*, Aug. 7, 1902, p. 103.
Apache Creek, San Antonio, Tex.	22.	704	Sept. 9, 1921	*Proceedings*, Am. Soc. C. E., Nov., 1921; *Proceedings*, Am. Soc. C. E., March, 1922.
Dry Run, Decorah, Iowa	22.3	720	March 15, 1919	*Eng. News-Record*, March 18, 1920.
Trout Brook, Brooksport, N.Y.	25.	158	....	*Transactions*, Am. Soc. C. E., Vol. LXXVII, pp. 572 and 614.
Pequonnock River, Bridgeport, Conn.	25.	157	July 29-30, 1905	*Water Supply Paper 162*, p. 1.
Spring Creek, above Dayton, Ohio	27.	210	March 23-27, 1913	Miami Conservancy Dist., Technical Repts., Part IV, p. 60.
Donnels Creek, above Dayton, Ohio	27.	147	March 23-27, 1913	Miami Conservancy Dist., Technical Repts., Part IV, p. 60.
Pinal Creek, Globe, Ariz.	30.	440	Aug. 17, 1904	*Eng. News-Record*, July 3, 1919, p. 31; *Water Supply Paper 147*, p. 118.
Sawkill River, Kingston, N.Y.	35.	228	Apr. 1895 also 1896	*Water Supply Paper 35*, p. 61.
Turtle Creek, above Dayton, Ohio	35.	175	March 23-27, 1913	Miami Conservancy Dist., Technical Repts., Part, IV, p. 60.
Lake Roland, Md.	39.	230	1868	*Transactions*, Am. Soc. C. E., Vol. LXXVII, pp. 572 and 614.
San Antonio River, San Antonio, Tex.	40.	140 200	Oct. 23, 1914 Dec. 2, 1913	*Water Supply Paper 438*, p. 59.
San Antonio River, San Antonio, Tex.	32.4 41. 45.	960 to 1200 580 333	Sept. 9, 1921	*Proceedings*, Am. Soc. C. E., Nov., 1921.

TABLE 5.—(*Continued.*)

Stream and Locality.	Drainage area, in square miles.	Flood flow, in cubic feet per second per square mile.	Date of flood.	References.
Cameron Creek Hurley, New Mexico	44.	125	Aug. 14, 1913	*Water Supply Paper 358* p. 662.
Elkhorn Creek, Keystone, W. Va	44.	1 363	June 22, 1901	*Eng. News*, Aug. 7, 1902, p. 104.
Sixmile Creek, Ithaca, N. Y.	46.	195	June 21, 1905	*Water Supply Paper 162*, p. 3.
Pine Creek, Paris, Tex.	48.	320 to 410	May 12, 1920	Letter from John B. Hawley, M. Am. Soc. C. E.
Little Conemaugh River, Johnstown, Pa.	48.6	206	May 30-31, 1889	*Transactions*, Am. Soc. C. E., Vol. XXIV, p. 431.
Lost Creek, above Dayton, Ohio	52.	571	Mar. 23-27, 1913	Miami Conservancy Dist., Technical Repts., Part IV, p. 60.
Santa Ysabel Creek, near Mesa Grande, Calif.	53.4	395	Jan. 27, 1916	*Water Supply Paper 426*, p. 56.
Tawawa Creek, above Dayton, Ohio	54.	239	Mar. 23-27, 1913	Miami Conservancy Dist., Technical Repts., Part IV, p. 60.
Ludlow Creek, above Dayton, Ohio	65.	266	Mar. 23-27, 1913	Miami Conservancy Dist., Technical Repts., Part IV, p. 60.
Dry Creek, Pueblo, Colo.	70.	300	June 2, 1921	*Proceedings*, Am. Soc. C. E., Nov., 1921.
Gallinas River, Las Vegas, N. Mex.	89.	131	Sept. 29, 1904	*Water Supply Paper 147*, p. 138.
Putah River, Guenoc, Calif.	91.	270	March 10, 1904	*Eng. News-Record*, July 3, 1919, p. 31; *Water Supply Paper 298*, p. 370.
North Fork Creek, Brookville, Pa.	97.	124	July 17, 1912	Pa. Water Supply Comm. Rept., 1912, p. 49.
Otay River, Lower Otay Dam, Calif.	98.6*	379	Jan. 27, 1916	*Eng. News-Record*, July 3, 1919, p. 31; *Water Supply Paper 426*, p. 44.
San Jacinto River, San Jacinto, Calif.	108.	278	Jan., 1916	*Eng. News-Record*, July 3, 1919, p. 31; *Water Supply Paper 426*, p. 70.
Santa Ysabel Creek, Ramona, Calif.	110.	258	Jan. 27, 1916	*Eng. News-Record*, July 3, 1919, p. 31; *Water Supply Paper 426*, p. 56.
Devil's Creek, Iowa	143.	600±	June 10, 1905	*Water Supply Paper 162*, p. 26, Meyer's "Hydrology", p. 134.
Mora River, La Cueva, N. Mex.	159.	140	Sept. 29, 1904	*Water Supply Paper 147*, p. 127.
Sweetwater River, Sweetwater Dam, Calif.	181.	251	Jan. 27, 1916	*Eng. News-Record*, July 3, 1919, p. 28; *Water Supply Paper 426*, p. 48.
Cave Creek, Phoenix, Ariz.	200.	125	Aug. 21, 1921	*Eng. News-Record*, Sept. 15, 1921, p. 464.
San Luis Rey River, Mesa Grande, Calif.	209.	280	Jan. 18, 1916	*Eng. News-Record*, July 3, 1919, p. 31; *Water Supply Paper 426*, p. 61.
San Luis Rey River, Oceanside, Calif.	564.	125	Jan. 26, 1916	*Eng. News*, Feb. 24, 1916, p. 383.
Santa Catarina River, Monterrey, Nueva Leon, Mexico	544.	432±	Aug. 27-28, 1909	*Eng. News-Record*, July 3, 1919, p. 28; *Eng. News*, Sept. 23, 1909; *Transactions*, Am. Soc. C. E., Vol. LXXII, p. 523.
Fountain Creek, Pueblo, Colo.	930.	54	June 3 1921	*Proceedings*, Am. Soc. C. E., Nov., 1921.
Arkansas River, Pueblo, Colo.	1 740.	57	June 3, 1921	*Proceedings*, Am. Soc. C. E., Sept., 1921.

* Measured on topographic map; 12.7 sq. miles tributary to Upper Otay Reservoir.

A most extraordinary flood discharge from a small drainage area is reported in the Water Resources Inventory Report* of the Pennsylvania Water Supply Commission, as follows: "The highest recorded flood occurred on Bull's Run, a small tributary of the Susquehanna River† on July 15th, 1914, which discharged at the rate of 5 000 sec-ft. per sq. mile from a drainage area

* "Floods", Part VIII (1917), p. 18. Also, pp. 70 and 128 of Vol. III, "Gazetteer of Streams", where the drainage area is given as 0.7 sq. mile.

† South of Wrightsville, Pa.

a little over ½ sq. mile". This rate of run-off is equivalent to 7.8 in. of water per hour on the drainage area. This would be an extremely high rate of precipitation for a period as short as 5 min.; while the period of concentration for a drainage area of 450 acres would probably be not less than 20 min. It may be, therefore, that this phenomenal flow resulted from the giving way of some obstruction rather than from the natural run-off following an excessive rain, and this record has accordingly been omitted from Table 5. Rates of precipitation as high as 7.80 in. per hour, for periods of 20 min., have been reported by the U. S. Weather Bureau only twice during the 18 years, 1901–18, inclusive,* as follows: April 29th, 1905, Taylor, Tex., 8.25 in. per hour, and, October 20th, 1909, Pensacola, Fla., 8.64 in. per hour.

J. Albert Holmes,† M. Am. Soc. C. E.—In the structures described by Charles H. Paul, M. Am. Soc. C. E., composed of impermeable cores and permeable dikes, the core is the real "dam", but its entire success depends on the stability and rigidity of the dikes.

In geological formations, clays and sands, formed by ice or streams, are deposited in water and, as great depths are laid down, are subjected to enormous pressure, converting the clays to shales and slates and the sands to sandstones and quartzites. Similar action takes place to a less extent in earth-fill dams and to determine its extent and effect, some experiments have been made on the core materials of two dams,‡ in which samples of the core were placed in a metal tank, pressure applied to the material at increasing rates, and the quantity of seepage measured after each pressure application. In these experiments, it was found that when the material was first placed in the test tank and before settlement had taken place or pressure had been applied, the seepage rate was high.

This loose condition and high seepage rate is analogous to the conditions existing in the upper layer of a core when first deposited in the pool. As the overburden increases, the core is consolidated, the voids decreased, the surplus water expelled, and the porosity diminished. In the experiments an increase in pressure from 150 to 3 400 lb., about 1½ tons per sq. ft., caused a reduction in the seepage rate of more than 90% and a decrease of 22.7% in volume of material from the loose condition.

The results of the tests, plotted on logarithmic paper, give the data in Table 6, in which the maximum rate or quantity of water that will filter through the core material of the two dams, with a loss of head equal to the thickness of the sample, is given in gallons per acre per day.

Within the limits of the test, the compression amounted to 20%, with an application of only 1 ton per sq. ft.; under additional pressure, the consolidation was less rapid, 2 tons per sq. ft. increasing it only 4 per cent. The percentages of settlement are based on dry, loose material and are to be considered as only approximate beyond the limits of the pressures applied. The seepage quantities are reduced to a uniform temperature of 50° Fahr.

* *Engineering News-Record*, Vol. 82 (1919), p. 1066.

† Chf. Engr., Decatur Dam, Pearse, Greeley & Hansen, Decatur, Ill.

‡ "Some Investigations and Studies in Hydraulic-Fill Dam Construction", by J. Albert Holmes, M. Am. Soc. C. E., *Transactions*, Am. Soc. C. E., Vol. LXXXIV (1921), pp. 331–358.

TABLE 6.

Pressure, in pounds per square foot.	Percentage of compression, approximate.	Seepage at Dam No. 3, in gallons per acre per day, 1:1 slope.	Seepage at Dam No. 4, in gallons per acre per day, 1:1 slope.
2 000	20	20 500	63 500
4 000	24	11 300	44 700
6 000	27	10 700	35 300
8 000	29	9 000	29 500
10 000	31	7 900	25 600
12 000	33	7 100	22 900
14 000	35	6 500	20 600
16 000	37	6 000	19 000

Darcy's law of the flow of water through a column of soil, in which the flow is directly proportional to the head and inversely to the length of the column, is modified by the effective size of the soil grain, the temperature (viscosity of the water), the percentage of voids, the porosity, and the presence of vegetable and colloidal matter.

The effective size of the soil grains in dam cores is small. They are so small, in fact, that the flow does not seem to be influenced by the size to nearly the same extent as in filter sands.

In experimenting with small volumes of material, the temperature (viscosity of the water) is important. To determine its actual temperature within the sample is difficult, but in order to get correct results this should be done. To obtain temperatures in the core of a dam would be still more difficult, but it could be accomplished, although the probabilities are that the slow moving water does not change much within the great mass of earth, but retains a nearly uniform temperature as does the water issuing from springs.

Percentage of voids (porosity) is of much importance. To their reduction by pressure (compacting) is due the stability and imperviousness of the core; imperviousness is increased by the presence of vegetable and colloidal matter.

It has been shown that dry clay, when confined and not allowed to expand, will absorb only about 3% of water, but if permitted to expand, it will take up water in proportion to its increase in volume. Also, that clay under pressure will give up its water in the presence of water.

Equal pressures reduce like materials to the same consistency, that is, a pressure of 3 tons per sq. ft. will reduce the moisture content of a pure clay to about 27%, and repeated trials bring about the same results without regard to the quantity of water originally present. A moisture content of 27% corresponds to about 50% of voids and, in the experiments, the clay was reported as "much hardened." An increase of pressure to 6 tons per sq. ft. reduced the moisture to 23% and the voids to 44 per cent.

These results come about quickly under experimental conditions using small volumes and more gradually in the large masses of material in the cores of the dams.

With stable and immovable dikes, compactness and stability of the core is sure to exist, and the speaker's thought is that, perhaps, where this has not

occurred and movement of the dikes was taking place at intervals, the core retained its moisture and volume, although, later, when the structure had changed its form and had become stable, the same material consolidated and gave up its moisture content.

D. W. Mead,* M. Am. Soc. C. E.—In 1914, the speaker had an opportunity to see some of the country described by John R. Freeman, President, Am. Soc. C. E., in his discussion of flood problems in China, and was also impressed with the ingenuity of the Chinese in their utilization of local resources for flood protection, such as clay and reeds—the only materials available in many places along the Grand Canal—to prevent erosion and to build temporary dams.

The speaker, however, was most impressed by the fact that here was a people who had 4 000 years of practical experience in hydraulic work, and although successful in minor details, they had, on the broad general principles, made an utter failure of their projects, because they had no correct fundamental theory on which to base their work. Those things that they could learn by practical experience, had been learned well—masonry work, protection work, and many things in which experience really counted; but on broad principles they had had no advantage of a sound theoretical basis, and their work, in general, was exceedingly defective.

Chinese education has been classical, not scientific, and their great men, educated in the Chinese classics and with no knowledge of science, have been unable to correlate the experience of the past and apply it to the practical uses of the present. They recognize an outlet as necessary for the discharge of flood water, but have no conception of capacity. One of their most highly educated men conceived, for the Huai River floods, an outlet 200 ft. wide by 10 ft. deep, which should have been 2 000 ft. wide by 20 ft. deep. To the solution of these great flood problems, China has brought centuries of experience, but no scientific knowledge, and years of practice without a correct theory. The impression left on the speaker's mind, by his observations in China, was the necessity of sound theory as a basis for correct practice.

The school of practical experience is exceedingly valuable, and usually correct theoretical analysis must be demonstrated by the results of such practice before the theory is of much value or can be safely adopted. As a basis of future practice, practical experience is, however, of comparatively little value unless the conditions are considered and studied and all the facts correlated and combined into a correct theory, from which experience can be extended to greater things. Without correct theory, the value of practical experience is limited to a reproduction of the experience under identically similar conditions, and as no two sets of conditions are ever exactly similar, the experience so applied is liable to failure on account of the introduction of factors which the previous experience does not include.

Real advancement is attained only through a combination of theory and practice. Each is incomplete and often dangerous without the other, but, by parallel development, safe and substantial progress is possible.

* Professor, Hydr. and San. Eng., Univ. of Wisconsin, Madison, Wis.

It is gratifying that so many members of the Society are working along these lines of investigating the facts, correlating them, developing the theory that will explain those facts, and carrying out effectively work for protection against floods.

ARTHUR O. RIDGWAY,* M. AM. SOC. C. E.—In Colorado and in the Colorado Rockies, all floods are of the cloudburst type. The Continental Divide describes a sinuous course through the State of Colorado in a general northerly and southerly direction. It covers 2° of longitude—1° on either side of the 106th Meridian—is about 290 miles in length, and at no place in that length is it less than 10 000 ft. in altitude. Little trouble with cloudbursts is experienced on the western slope of the Rockies. The eastern slope receives much less precipitation than the western slope, especially in the form of snow, and there all the floods come from cloudbursts.

The first problem in the floods of the Colorado Rockies is the distribution of the precipitation. In one drainage area, the mean annual precipitation will vary from 9 to 25 in., computed over a period of 40 or 50 years, and of this, rainfall contributes much the larger proportion. The rainfall does not come in general storms; it is practically all confined to sudden and intense thunderstorms, of which there is often a rapid recurrence. There may be three or four in the same locality during an afternoon. Apparently, there is no law of their occurrence; in one tributary, there may be a severe storm with the next tributary dry.

Another problem is the suddenness and the intensity of the storms. The clouds gather quickly, drop their load as it were, and are gone. The movement of the storms is peculiar. Recently, a series of storms moved down the Colorado River on one side of the drainage basin and, at the same time, another series was moving up the river on the opposite margin.

There are no authentic records as to the intensity. The weather stations, although quite close together, are inadequate for determining precipitation of these intense and highly concentrated storms. In an area over which the precipitation will average 10 to 15 in. per year, as much as 14 in. of rainfall is known to have fallen in a single afternoon or evening, and as much as 5 in. in 30 min. At Pueblo, in the Arkansas drainage, two storms are recorded in which about 2.0 in. fell in less than 1 hour or, to be more exact, one storm of 2.02 in. in 50 min. and another of 1.78 in. in 36 min.

The next problem is coincidence. There are many factors that militate against the determination of flood flows in tributaries. The precipitous slopes, the irregularity of the gradients of the streams, and the recurrence of the storms themselves, with apparently no law of occurrence, make it impossible to compute with any degree of reliability the probable coincidence for the floods in the tributaries.

Perhaps the greatest problem is contributed by the high velocities of flow in the streams of the Colorado Rockies. The country, literally, stands on end; stream velocities of 18 to 20 ft. per sec. are common, which make it difficult to deal with floods in this region. The high velocities bring down a great deal

* Asst. Chf. Engr., Denver & Rio Grande R. R., Denver, Colo.

of débris, which helps to give additional power to the water, so that the floods are very destructive.

The suddenness and intensity of the storms with their enormously high run-off rate may be illustrated by the Arkansas River flood of June, 1921. The discharge of the river increased forty or fifty times in 7 hours. Some tributaries of the Arkansas, dry at the beginning of the storm, were, a few minutes later, discharging from 35 000 to 40 000 sec-ft.

Summarizing, the speaker would state that the real flood problems in the Colorado Rockies are: First, erratic distribution of rainfall; second, great intensity of storms over small areas and their rapid recurrence; third, difficulty of foreseeing or foretelling the coincidence of tributary floods; and, fourth, the high velocity of the flood waters.

There might be added another problem of rather a psychological or sociological character. People want the water and, to them, it seems no less than an economic crime to provide means for its getting away. If the channels are improved, their discharge is increased, and the water runs away more rapidly. Especially on the eastern slope of the Rockies, is it wanted for irrigation. Therefore, when flood protection is attempted one gets into difficulty because of the fact that every one wishes to conserve all the water.

J. B. Challies,* M. Am. Soc. C. E. (by letter).†—The river-control problems that have been solved in Canada have been largely for power purposes, but in many cases these projects incidentally result in bettering flood conditions.

La Loutre Reservoir.—The La Loutre Reservoir on the St. Maurice River, in the Province of Quebec, was constructed and operated by the Quebec Streams Commission. It was completed in 1917 and has a capacity of 160 000 000 000 cu. ft. This storage has increased the power available on the river by 400 000 h. p., and the control is also of much benefit to logging operations, particularly in breaking log jams by controlled flood waves released from the reservoir. The Quebec Streams Commission also carries out important storage operations on the St. François River, mainly for the benefit of the numerous power developments on that stream.

Ottawa River Storage.—Storage undertakings on the Upper Ottawa River, carried out by the Dominion Department of Public Works, include three reservoirs with a total capacity of 125 000 000 000 cu. ft., used to benefit the large power sites on the river, the potential power of which is more than 1 000 000 h. p., and also logging and navigation.

Trent Canal System.—The two examples previously mentioned are typical of control from one or a few large storages, whereas in the Trent River System, the control is from a large number of relatively small storages. Dams have been built at the outlets of many lakes on tributary streams, which supply the canal system on this river and supplement the minimum flow for power purposes.

Although the various storage works mentioned are primarily for power development and navigation, they have a marked effect on the control of floods.

* Director, Dominion Water Power Branch, Dept. of the Interior, Ottawa, Ont., Canada

† Received by the Secretary, April 5th, 1922.

Many of the Canadian rivers present problems in which flood control is of primary importance and a few typical examples in the various Provinces may be of interest.

Floods in British Columbia.—In British Columbia, a disastrous flood occurred in the autumn of 1921. A rainfall of more than 15 in. in 26 hours caused the Coquitlam River to flood, resulting in much destruction. A discharge of 24 000 sec-ft. was recorded, as compared with a previous recorded maximum of about 12 000 sec-ft. A consoling feature was that the dam controlling the waters of Coquitlam Lake withstood this test and that the factors of safety insisted on, in its construction, by John R. Freeman, President, Am. Soc. C. E., have been justified. The Coquitlam Dam, the first hydraulic-fill dam built in Canada, is 1 200 ft. long with a maximum height of 100 ft. and an extreme width at the base of 655 ft. On the same occasion, in an adjacent water-shed, at Britannia Mines, even greater calamity was caused by flood, including the loss of thirty-six lives. The power and storage dams did not give away and the flood was probably lessened greatly by them.

The problems which have to be faced at the delta of the Fraser River in this Province are also associated with flood prevention. The discharge of this river has varied from a maximum of about 380 000 sec-ft. to a minimum of 12 000 sec-ft. and accumulations of snags, trees, and silt must be removed regularly and dredging operations have to be carried on for navigation, thus, also, preventing serious floods. Silt problems in this river resemble somewhat those of the Mississippi, and interesting results are anticipated from the co-operative study undertaken by the Dominion Department of Public Works and other Government and technical organizations as to their best solution.

Floods in Alberta.—In the Province of Alberta, floods often result from high summer temperatures, which cause an excessive melting of the snows in the mountains.

In June, 1915, the North Saskatchewan River at Edmonton rose 38 ft. above low water and 800 families were temporarily rendered homeless by this flood.

To the south, in the same Province, floods have occurred on the Bow River in 1879, 1884, 1897, and 1902, when, in each instance, a part of the City of Calgary was under water. Escape from flood in 1915 is attributed to the weather turning suddenly cold during the warm period which caused the Edmonton flood, thus stopping the excessive melting of snow in the mountains.

The many uses of the Bow River, including water supply, irrigation, and water power, would tend to encourage further artificial control of its waters, but the low winter temperature, subject to sudden changes, presents difficult conditions for efficient storage operation.

Floods in Manitoba.—In Manitoba, records of floods on the Red River of the North are available from various sources for a great number of years, and floods, reported as particularly serious, occurred in 1776, 1790, 1809, 1826, 1852, and 1861, when, in each case, the plain on which the City of Winnipeg is built was inundated. The river drains to the north, and the spring thaw in its upper water-shed brings down flood waters to the lower reaches before the complete release of ice has occurred and the contracted channel below Winnipeg also contributes to flood conditions. The control methods considered

include reservoirs in the upper drainage areas and overflow discharge from the Assiniboin River, a large tributary, to an adjacent basin, together with dikes and improvement of the river channel. Following the flood damages of 1916, in that part of the basin in the United States, the co-operation of the Manitoba and Dominion Governments was requested to remedy conditions.

Floods in Ontario.—Lake of the Woods, between the Provinces of Manitoba and Ontario, has lately furnished a typical example of how flood conditions can be alleviated materially by proper storage control by a responsible public organization.

In 1916, previous to the placing of the regulation of the Lake under the direction of the Lake of the Woods Control Board, a notable flood occurred in this drainage area. In contrast with this, in 1919, when the Lake of the Woods Control Board was exercising its jurisdiction, conditions which naturally would have had far more disastrous results, were anticipated and coped with successfully. Prompt action at the control works was made possible by telegraphic communication from the various meteorological stations reporting heavy rainfall, and although the inflow rate to the Lake became twice that of 1916, systematic and intelligent regulation enabled the Board to cope successfully with the situation.

Farther east, in Ontario, the Grand River presents a flood-control problem which, during the past decade, has often been discussed at professional meetings. The situation is aggravated by the large number of important centers at various points along this river, which are more or less affected by the undue rise of its waters. Among these centers are Brantford, Kitchener, Woodstock, Galt, Waterloo, Preston, Hespeler, and Paris.

The recent recorded flow of the Grand River shows a maximum of 37 000 sec-ft. and a minimum of only 24 sec-ft., and its floods are attributed to the destruction of great forest areas. The drainage of hundreds of square miles of swamps in the head-waters have changed moderate floods and sustained flow to destructive floods and gradually disappearing flow.

The floods of the Grand River are caused by spring freshets, and storage works for combined flood control, water power, and irrigation have been suggested.

St. Lawrence River.—Trouble from flood would hardly be expected on the St. Lawrence, with its great natural reservoirs and well regulated flow. This stream, however, furnishes an example of floods caused, not by an excessive discharge, but by the blocking of its channel by ice at certain points. The disastrous floods on the St. Lawrence, in the vicinity of Cornwall, in 1840, 1879, 1887, 1895, 1898, 1901, and 1905, were caused by ice jams.

In February, 1887, ice jams caused the water to rise 31 ft. above normal summer level, at a point above Cornwall, inundating two-thirds of that town.

Floods in Quebec.—In the Province of Quebec, a disastrous flood occurred on the Chaudière River in the latter part of July, 1917, and serious spring floods have been recorded on this river in 1885, 1896, and 1912. Its most important tributaries, rapidly descending their steep courses, enter the main stream within a distance of 13 miles, just above a long section of the river that has low banks and a narrow channel, where the effect of floods is particu-

larly disastrous. The Chaudière flows to the north, and the spring floods are caused by freshets and ice accumulation from its southern drainage reaching the lower parts before the break-up has occurred. The maximum spring discharge has reached 42 500 sec-ft., as compared with a minimum flow of only 200 sec-ft. The discharge, during the summer flood of 1917, following a rainfall of 5.42 in. in 15 hours, was estimated at 125 000 sec-ft. and caused a rise of water of 30 ft. with losses estimated at $1 315 000. The Quebec Streams Commission has considered a number of reservoirs for flood control on this river.

The flood control of the Chateauguay River is also being studied by the Quebec Streams Commission. This stream is another example of a river flowing north in which spring floods are caused mainly by an ice blockade in the lower part of the stream. The remedy proposed consists of creating conditions in the rapid upper part of the stream whereby a more substantial ice cover will be formed, and to retard and time properly its release in the spring.

General Remarks.—In this discussion, it has been possible to give only a brief summary of the most important flood problems facing the Engineering Profession of the Dominion. It may be of interest to state that, in proportion to population, Canada is spending much more on basic hydrometric work than the United States. Every Province is now covered by the Dominion Hydrometric Survey, the field, office, and publication methods of which are practically the same as those so successfully standardized by the Water Resources Branch of the U. S. Geological Survey.

George M. Lehman,* M. Am. Soc. C. E. (by letter).†—More attention should be given throughout the United States to the collection of data relating to the various flood troubles and to physical conditions of affected localities, including both improved and unimproved property, particularly the former.

Municipal and county engineers should be brought to realize the importance of recording at least the probable area and amount of notable local rainfall; heights of water, particularly of crest, at various points; velocities; discharge; duration and extent of land overflow; and the classified character and amount of damage, with its location, and such other happenings as may be of value.

It may not be feasible for all these things to be done by the local authorities, but a great deal could be accomplished without much trouble or expense in connection with the regular duties. After the accumulation of data extending over several years, localities not attempting construction of protective measures on any considerable scale would still receive guidance for general development.

In 1908, prior to the organization of the Pittsburgh Flood Commission and when suggesting that a study be made, the writer, as preliminary to the engineering work with which he later was connected, proposed the following: "To investigate the monetary loss, character of damage and areas affected

* Chf., Div. of Waterways, Dept. of Internal Affairs of Pennsylvania, Harrisburg, Pa.

† Received by the Secretary, April 5th, 1922.

by the floods in the Pittsburgh District, and secure such other information as may be of value as a basis for further consideration of plans for improvement."

It was further suggested that a part of this study include: (*a*) damage to buildings, equipment, and machinery; (*b*) damage to materials; (*c*) loss to employer by suspension of business; (*d*) loss to employees due to shut-down; (*e*) expense of clearing up; (*f*) charities dispensed and funds for prevention of disease; and (*g*) fires controlled through inaccessibility or lack of water pressure. In the classification mentioned, transportation lines, of course, were included.

Because the various interests affected were brought to realize the importance of the matter and generously to respond financially, it was possible to attain the extensive field and office results needed for the local engineering plans. Although the whole work included a drainage area of about 19 000 sq. miles above the city, in that part of the study relating to preventative means, by storage reservoir control, intensive study of special localities above Pittsburgh could not be undertaken as the requisite data were not available. To secure the needed information for all the municipalities would have required much time and a large additional amount of money, only attainable by a widespread and extensive campaign. It was found that reservoir control for Pittsburgh would also render flood reduction benefits to places above, and if each community had had the foresight to accumulate some useful information, the report could have been broadened to include at least many of those communities in a beneficial manner. The findings disclosed that the damage occasioned by the greatest recorded flood amounted to $5 300 000 in direct loss to Pittsburgh.

As illustrative of the importance of knowing conditions, a study was recently made of a portion of a river valley in Pennsylvania, having extensive valuable flat land in which is located a city of importance. The writer found that in a 17-mile reach, the area involved by the greatest recorded flood, amounted to about 6 980 acres. The width between flood flow lines, averaged about 3 400 ft., whereas the width of normal water, between banks, was about 700 ft. Protective measures by dikes was considered as the only means available, as given in a report in 1913 by an Army engineer. These works, the recent study disclosed, would reduce the affected area about 66 per cent.

Many features of vital importance to present and future generations were involved in this particular study. The increase to property values, alone, would be enormous with the flood menace, at least, largely under some form of control.

It is timely for the Society to discuss means for the guidance of municipal and county governments in accumulating useful information regarding floods. Would it not be well to have a special committee report on such a plan?

The State should accumulate the data collected and recorded by the municipal and county authorities. The advantage of such an arrangement is manifest. For a number of cases, special service would be rendered by a State representative.

W. H. Breithaupt,* M. Am. Soc. C. E. (by letter).†—The peninsula of Southwestern Ontario is bordered by Lake Huron and its extension, Georgian Bay, on the west and north, Lake Erie on the south, and Lake Ontario on the east. These large bodies of water form, in a manner, a meteorological barrier, mitigating if not arresting undue atmospheric disturbances. The level surface and its cool, equable temperature induce atmospheric conditions nowhere equalled on the land.

In Ontario, precipitation and, to some extent, general weather records extend back about seventy-five years. The Canadian Meteorological Service was organized in 1870, but observations had been made, to some extent, for a considerable time before. The average annual precipitation, rainfall and snowfall, has varied from about 30 to more than 40 in. In the high altitude region, in the northerly part of the area, the snowfall is heavy, attaining ordinarily 120 to 130 in.; one record (1879) is 153.8 in. The general average of precipitation has varied in cycles, up and down, but there appears to have been no fundamental change since the beginning. Since the first observations, there is no record of such extreme precipitations as have occurred several times during this period, in the region beyond the lakes.

Most of the heavy precipitation in the peninsula has its origin in the Gulf of Mexico. Consider the extreme rain storm that caused the floods of March, 1913, along the Miami River and its tributaries: In the area of maximum precipitation, in Eastern Indiana and Western Ohio, the total rainfall exceeded 6 in. prior to March 24th. The maxima from the beginning of the storm to the dates given were at:

Wooster, Ohio................	To March 26th........	9 in.
Upper Sandusky, Ohio.........	" " 26th........	8.44 "
Bangerville, Ohio.............	" " 27th........	9.5 "
Bellefontaine, Ohio...........	" " 27th........	11.16 "
Marion, Ohio.................	" " 27th........	10.6 "

In Cleveland, Ohio, on March 25th, 1913, the rainfall was 2.88 in.

At observation stations in Ontario, north of Lake Erie, the records for March 23d to 27th, 1913, are as given in Table 6.

TABLE 6.

Station.	Location	March 23d, 1913.		March 24th, 1913.		March 25th, 1913.		March 26th, 1913.		March 27th, 1913.		Total water, in inches.
		Rain, in inches.	Snow, in inches.	Rain, in inches.	Snow, in inches	Rain, in inches.	Snow. in inches.	Rain, in inches.	Snow, in inches.	Rain. in inches.	Snow, in inches.	
Port Stanley...	Lake Shore....	0.35	......	1.64	......	1.77	......	0.08	0.2	......	2.2	4.08
Port Burwell...	"	......	......	1.55	......	1.50	......	0.15	......	......	3.0	3.50
Port Dover.....	"	0.37	......	1.29	......	1.19	......	0.30	......	0.37	2.6	3.78
London	22 miles inland.	......	.....	0.92	......	1.34	......	0.13	0.5	......	2.5	2.69
Woodstock.....	30 "	0.66	......	0.05	......	0.64	......	0.02	......	......	3.3	1.70
Guelph.........	50 "	......	......	0.28	......	0.10	......	......	......	......	3.0	0.68

* Cons. Engr., Kitchener, Ont., Canada.

† Received by the Secretary, April 5th, 1922.

It will be noted from Table 6 that the precipitation is higher on the lake shore than inland, that some of it is snow, and that it is much less than the precipitation south of the lake. The totals for 1913, at the stations given, were as follows: Port Stanley, 41.8 in., Port Burwell, 36 in., Port Dover, 41 in., London, 43.6 in., Woodstock, 26.1 in., and Guelph, 28.5 in.

On the general question of the effect of forestation on stream flow, the writer will cite his personal observation of a smaller river for the past fifty years. It is held that for extreme conditions of both flood and low water, the influence of forested surface is detrimental, that forests neither retard the melting of snow, nor prolong the run-off. The most notable proponent of these views was the late Col. H. M. Chittenden, U. S. A. (*Retired*), M. Am. Soc. C. E.* Although for the special conditions in the Rocky Mountain region where, above the forestation line, enormous snowdrifts gather in the great clefts, and where, on the Pacific slope, there are dense forests of lofty evergreens—abnormal as compared to any other part of the Temperate Zone—where 12 in. of an 18-in. snowfall will lodge in the foliage exposed to quick melting by the "chinook" winds peculiar to that region, forestation may increase and bare areas retard the intensity of run-off, this does not hold, in general, elsewhere.

The influence of normal forestation on smaller rivers is so well established as to be beyond question. The Ontario Peninsula was a densely wooded area, of general forestation. All observers agree that the floods are greater and the dry-period flow much less than before deforestation, settlement, and the general clearing and farming of the land. Former springs and even brooks have disappeared, with deforestation. Rivers which in the early days, were routes of canoe navigation, are now small streams during the greater part of the year. For instance, the Humber River, with its outlet at Toronto, was on the main route from the western part of Lake Ontario to the Northwest. At present, except a few miles above its outlet, this river is now not navigable for canoes after the spring freshets.

All the rivers of the Peninsula have a much smaller summer flow than formerly, and greater floods in the spring. The Grand River drains essentially the central part of the Peninsula, and its drainage area on the plateau contains more than 400 sq. miles of swamp area. The entire water-shed of the river was originally heavily forested, the swamps also being covered with dense growth, mostly of cedar and tamarack. The high-water channel of 40 or 50 years ago, overflows almost every spring with the snow-melting and the breaking up of the ice. The ice is forced aside over the banks, and cuts at the trees which could not have grown under present conditions. The extreme flood which generally subsides quickly, leaves the heavy ice formation high on the banks for weeks; even with the light snowfalls of the winters of 1921 and 1922, this overflow and ice shove occurred. As to snow-melting the observance in Ontario is that snow disappears in open fields long before it does in the woodland. The head-water swamps were particularly valuable as snow retainers and great, spongy, natural reservoirs. Coincident with their drainage during the past 30 years, the summer flow of the river was reduced

* *Transactions*, Am. Soc. C. E., Vol. LXII (1909), p. 245.

to its present low level. This swamp drainage was, mistakenly, assisted by the Provincial Government, and thus a valuable asset was destroyed. Above Bridgeport, the summer low water is now generally about 35 sec-ft., and in the flood of 1912—the greatest on record—the flow was from 19 000 to 20 000 sec-ft.

The great river of Canada, the St. Lawrence, with its unique and superb natural flow regulators, the Great Lakes, has little variation of flow throughout the year. Local floods are caused by ice damming, and local lower water, as in the Niagara River, to long continued strong east winds, piling up the water in Lake Erie. An extreme flood on any component pouring into the Lake will cause only a minute difference in lake level, in head of outflow, and, therefore, in rate of outflow.

Relative to brooks and springs: In the County of Waterloo, with an area of about 600 sq. miles, there have been in operation during the course of its history, 112 water powers,* which supplied power mostly to saw-mills and grist mills. Only about 30% of these water powers continue to-day. Few saw-mills are left in the county, as most of the saw logs have been used long ago. The brooks which supplied some of the smaller water powers, are now dry for a great part of the year. Innumerable springs throughout the county have gone dry, many of them within the writer's own recollection.

On the Grand River, exceptional natural facilities exist for water conservation. This river is comparable to the Genesee River in New York State. It has a drainage area of 2 600 sq. miles, and is wide at the upper part, narrowing farther down stream. It rises within 25 miles of Georgian Bay and has a total fall of more than 1 100 ft. Its length, along its windings, is more than 160 miles and it empties into Lake Erie. The tributaries are the Conestoga from the west, rising on the plateau, the Speed from the east, and, lowest, the Nith from the west. Along the main river are three fast-growing cities and a number of towns, and the entire water-shed is one of the most prosperous sections of Canada. Extreme floods occur only in the spring and always come with snow-melting on the head-water area. Heavy rainfalls may cause a rise of 6 ft. or more in as many hours, owing to the quick run-off, but these floods do not overflow the main channel. The small low-water flow, which has greatly diminished existing water-power developments on the river, is a sanitary menace and is generally detrimental.

At the foot of the upper river, at Elevation 1 150, there is a basin which, closed by a comparatively low dam, will contain from 2 750 000 000 to 3 000 000 000 cu. ft. of water. Above the site is the heavy snowfall area, and a drainage of more than 450 sq. miles. The basin would be filled every spring, and replenished during the summer by the rainfalls. Further storage is practicable on the Conestoga where, with a drainage area of about 160 sq. miles above it, one dam will store more than 1 000 000 000 cu. ft. This will give more than 4 000 000 000 cu. ft. of storage capacity, sufficient to eliminate flood damage on the entire river below the dams and to give a minimum flow of 350 sec-ft., or more—eight to ten times the present low water on a large part of the river. The existing water-power developments would be greatly

* Investigation by Mr. E. W. B. Snider.

benefited and additional ones would be economically practicable at a number of places. Further, the conserved water, now destructively wasted, could be diverted and dropped over the Niagara escarpment to the level of Lake Ontario with a development of 15 000 h. p., or more. In a short time, the cities along it will have to depend on the river for their water supplies, if not directly on the contemplated storage basin which would give a much better water, both industrial and potable, than the present low summer flow of concentrated hardness and contamination.

ADOLPH F. MEYER,* M. AM. SOC. C. E. (by letter).†—The economic justification for the large expenditures that these great flood-protection projects have entailed has not been thoroughly discussed. Descriptions have been given of towering retaining walls, mountainous fills, miles of bank revetment, thousands of feet of diversion weirs and spacious by-pass channels, and the millions of dollars in assessments paid for the construction of these gigantic works have been cited. To preserve the balance, should not the millions which these projects will return to the investors, have been pictured in equally bold relief?

Each drainage basin subject to floods must be studied as a problem in itself. The gravest danger lies in wrong applications of good solutions. Reference has been made to the general opposition to reservoir construction during the early development of the Miami Project. In other communities, similar opposition is voiced against levee construction, on the Lower Mississippi, for example. Political spellbinders who picture the gathering of flood waters into tremendous reservoirs for later beneficial use in power development and in the increase of navigable depths in streams, are applauded by audiences that give an unsympathetic ear to the engineer who points out that the structures required to utilize flood waters available only once in 5 or 10 years will never return interest on the investment, and that storage for flood prevention and beneficial use are essentially antagonistic.

Engineers are primarily responsible for the false notions which the general public possesses regarding most flood problems because they too often fail to emphasize why, on one stream, the correct solution of the flood problem is not necessarily applicable to other streams; why automatic retarding basins are the best solution in one case, levee construction in another, cut-offs and by-passes in another, and manually controlled reservoirs in still another. If engineers would mould public opinion on such vital questions as flood protection, the writer believes they should place greater emphasis on these phases of their projects for the benefit of the public.

The cost of every flood-protection project must be justified to those who pay for it. The comparative cost and accomplishment of the projects, do not stand out as prominently as they might. The fact that communities in Ohio have spent $35 000 000 for the control of floods on a water-shed of 3 500 sq. miles is not *prima facie* evidence that communities in Minnesota can afford to spend $2 000 000 for the control of floods on a basin of 16 000 sq. miles.

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* Cons. Hydr. Engr., Minneapolis, Minn.

† Received by the Secretary, April 5th, 1922.

The protection of agricultural lands is one of the flood problems in Minnesota. A typical example is that of about 100 000 acres of rich bottom-lands in the Minnesota River Valley. Some of these lands are flooded on an average, every 2 or 3 years, others less frequently. Having determined the extent and frequency of flooding from the best available sources, this problem resolved itself into determining how much protection offered the greatest return, on the investment and how this protection, if worth while, could be most economically secured. Although these studies have not been fully completed, the answers are:

First.—It does not pay to protect agricultural lands from crop losses through rare floods, that is, floods that will not recur, on an average, once in about fifteen years.

Second.—When lives, farm buildings, city property, or other important improvements are not endangered, it does not pay fully to protect the flood-control structures themselves against floods unlikely to recur once in a century or more.

Third.—Protection of these agricultural lands must be secured through the construction of manually controlled storage reservoirs, combined with the provision of reasonable bank-full carrying capacity in the channels below.

A full statement of the reasons for these conclusions cannot be undertaken in a short discussion, but the writer will state that the cost of levee construction and channel improvement cannot be justified by the crop savings affected, even if there were no other objection to these methods of flood protection on this stream.

Every large tributary of the Minnesota River flowing down steep slopes from the uplands, into the valley of the main stream, has either succeeded in blocking the stream sufficiently to form a lake or to produce a long flat reach above the point of debouch. These lakes and the longest reach of the stream where the slope is flat, have been selected as sites for three reservoirs.

Below the proposed reservoirs, the stream has steeper slopes and relatively larger capacity, that is, from one-sixth to one-fourth of the capacity necessary to carry off, at bank-full stage, a 25-year flood. At the extreme upper end of the valley, the channel will carry only about one-twentieth of such a flood. For this reason, flood water stored in the upper reservoir must be discharged over a period of several months, in wet years. This fact alone shows the impracticability of automatic retarding basins for this stream. The smaller the drainage area the larger the ratio of the flood flow to the bank-full capacity, hence, the greater the required storage reservoir per square mile of tributary drainage area.

The Minnesota River reservoir farthest down stream will be filled most frequently, but may be emptied again in a few weeks. In fact, this reservoir comes nearest to having the characteristics of an automatic retarding basin. Even this reservoir, however, must be closed off entirely at times, for a day or two, in order to give the single large tributary which enters just below, the right of way in the main channel.

The writer believes it may be set down as a fundamentally correct principle, applicable not only to the Minnesota River, but to most other streams,

that both the length of time over which flood water should be detained and the quantity of water which should be detained per square mile of tributary drainage basin for flood protection purposes, decrease down stream. The flood-plain of most large streams, particularly in the lower reaches, affords a detention basin of no mean proportions. Levee construction preserves and enlarges these natural basins.

In conclusion, the writer would reiterate that he believes an endeavor should be made to emphasize more strongly the basis on which each flood-protection project is economically justified, and the factors that in each case made the solution adopted, the best one, if engineers would prevent the formation of prejudices, both within and without the Profession, for and against all methods of coping with this most vital problem.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE NATIONAL HOUSING PROBLEM*
A SYMPOSIUM

BETTER LIGHTING AS A PART OF BETTER HOMES

By Samuel G. Hibben,† Esq.

The subject of lighting in residences and homes is of interest, partly because so little is known about it and partly because it is such a rapidly growing science.

The scientist or the engineer usually wants to discuss a subject in terms that are concrete or clear, and there are three well known terms used in all discussions of illumination, namely, "candle-power", "foot-candles", and "lumens".

Candle-power is a common term. An illuminant, whether it is a lamp or a larger diffusing unit, will radiate light with a certain pressure, or candle-power. People are not concerned with the "pressure" of radiation of light, only so far as it may cause harm to the eyes. They are concerned, however, with the amount of illumination on a working surface, because if they were to attempt to see a paper on a desk top or a picture on the wall, they could only see it by virtue of the amount of light falling on it, and reflected from the paper or the picture to the eye.

To measure the illumination on a surface, the term "foot-candles" is used. If snow was to fall to the thickness of 1 ft., one would obviously say the depth of the snowfall was 1 ft. Similarly, the thickness of lightfall on a surface is measured in foot-candles. The instrument to measure the lightfall is called a foot-candle meter.

The quantity of light is measured in terms of "lumens" and is the product of the area illuminated and the foot-candles of illumination on that area.

In the application of light, one wishes to know the amount, the direction, and the color. To the physicist, color is merely a matter of wave length, and

* Presented at the meetings of January 4th and 5th, 1922, and continued from March, 1922, *Proceedings*.

† Illuminating Engr., Westinghouse Lamp Company, New York City.

can be controlled by absorbing certain wave lengths, either in transmission through glasswear or reflection from wall surfaces, or a selected light source of a given wave length may be used and, therefore, of color.

In common practice there is a wide range in color and amount of illumination. The eyes have become accustomed to this variation so that, over short periods of time, one can scarcely notice when there is too much or too little light, unless measuring instruments are used or the conditions are investigated quite thoroughly. For that reason, the subject of illumination in the home needs careful engineering attention, because the eyes of children—adolescent eyes—that may continue to function under insufficient illumination, nevertheless, may be straining all the time, until some serious difficulties result. Conversely, the eyes may be exposed to the rays of bright, glaring lamps. Every one suffers from glare in the same way, but the evil is insidious and affects, particularly, children and elderly persons. The resultant eye troubles are sure to come, although in a slower or milder form. Headaches and similar troubles are caused by eye strain under glare.

Any one individual may safely say that a study of home lighting does not seriously concern him, but with a community, or a group of people, as exemplified by a large office building, the possible economies or the possible losses must be considered. The economies that a person in his own home might consider to be negligible, will represent, over an entire community, a great saving. One may be astonished to find that in his home or office he can use a light gray or white shade of wall or ceiling and a 40-watt incandescent lamp, and receive the same amount of light on his desk as with a dark yellow or green shade and a 60-watt incandescent lamp. The amount of light reflected from different colored surface varies. Probably 80% of the light is reflected from a good white colored surface, but only 35 or 40% from medium red or tan shades, and perhaps 10% from the dark green.

The average decorator and housewife does not seriously consider the effect of interior colors, wall paper, and finishes on the amount of useful illumination. The kind of paint should be considered, because it has been discovered recently, that paints of the same color, but made from different constituents, will reflect different amounts of light. One can easily demonstrate by mixing lamp black with a white paint, thereby getting the same shade of gray as perhaps from other mixtures, such as green and vermilion. The lamp-black gray reflects less light than the same shade of color made from a green and a red. Lamp black is a heavy absorber of light.

There are many other factors in economic lighting that the home owner may ill afford to overlook. The position of lamps, whether burning tip up or tip down or sidewise, may shorten the life considerably. The proper voltage for Mazda lamps is important. In one modern residence some of the lamps were for 110 volts and some for 115 volts. The question was asked, "What difference does it make? They both burn." The answer is, "If the voltage is 115 and the lamps are for 110 volts, their life will be reduced about one-half. If the voltage is 110 and the lamps are for 115 volts, about 85% of the possible light is obtained."

Another matter in this illuminating problem is that there is probably as much difference between the amount of light absorbed in various glasses as there is in colored paints. A good quality of opalescent glassware may transmit 85% of the light, whereas a poor quality will transmit only 60 per cent. A great mistake is made in most artificial lighting installations in not studying the question of the glassware. A few years ago, the crystal rough frosted glass was used almost exclusively. It was not a good diffuser and was a heavy absorber of light. At present, it is rarely used and then in the cheapest type of lighting fixtures. Its low first cost is lost many times over, through its inefficiency.

The selection of window or sheet glass, used sometimes in skylights and particularly in windows and partitions, is important. The prism window glass has never been seriously studied from the standpoint of lighting, and yet it can be easily demonstrated that a piece of prism or ribbed window glass if turned with the prisms to one side or the other, might change the amount of useful light in a room by 30 or 40 per cent. In other words, if a ribbed glass with the prisms on the inside, or running in the wrong direction, was used in windows where the light comes from without, comparatively little light would be obtained in the rooms. If the prisms are placed on the side from which the light comes, the illumination might be increased 50 per cent. Many good architects have never thought of this matter; they will place windows or partitions with ribbed or prism glass in them, but the idea of placing the rib one way or the other was never investigated.

About a year ago, it was ascertained that of the 30 000 000 or 35 000 000 homes in the United States, only about 6 000 000 were wired for electric light, so that there is a possibility of much improvement in extending the use of electricity for residence lighting. Also, for every 16 or 17 rooms in a house, there is only one convenient outlet, such as a baseboard or plug receptacle. It is surprising that many people in buying, building, or planning homes, forget that the electrical conveniences—portable table lamps, stoves, cooking devices, fans, etc.—must first have an outlet provided for them. In some of the modern apartments it is difficult to find good places to attach electrical conveniences, that might be used if the attachment facilities were available.

Take the average residence, for example, in the kitchen one finds far too many installations in which a bare incandescent lamp is used, hanging somewhere over the stove. This arrangement is not only detrimental to good vision, but it is uneconomical. The maximum amount of light from the bare lamp is sent out sidewise and much goes upward, with relatively little projected downward. It is downward, on the stove, that the illumination is wanted, and it would require perhaps 5 or 6 foot-candles on this surface to enable a person to see properly. Yet, from 12 to 20 foot-candles are used on the upper part of the room and practically none on the working surfaces, except what may be reflected from the ceiling or opposite walls on the stove.

The use of combination gas and electric fixtures is poor practice. Too often the electric lamp is too low to illuminate a large area, or points out at an angle that is inefficient. It is better to have the emergency gas-bracket within reach, and a ceiling electric unit controlled by a pull-chain or wall switch.

Many equipments, even in modern homes, use a larger lamp than is intended for the reflector. The lamp bulb extends about half way out of a decorative but inefficient, glass shade. Any lamp that projects out of the reflector is not operating satisfactorily. The ideal method is to have the tip of the lamp bulb about level with the bottom edge of the reflector.

Entrance doorways of the home are quite well lighted by brackets, in some cases the house numbers being painted on the glassware. The usual mistake with such porch brackets, is that they are located behind opening doors and every time the wind or the children throw the screen door open, the glassware is broken.

In many residences, one still finds the old dome hanging over the library table in service. It is not bad if the lamps are placed far enough in it so that the exposed filaments of the incandescent lamps are not visible. Consequently, if that sort of fixture is used, a screen of silk should be placed under it, or a piece of diffusing cloth, anything that will shade the eyes from the direct view of the light bulb.

The cleaning of lighting devices is important. Glassware, lamps, even walls, all need better attention than they usually receive, and the dust that will accumulate in a month may reduce the illumination 30% or more. Attention should be called to the fact that either a deeply shielded lamp, a rather dense semi-indirect bowl, or an inverted opaque bowl, are excellent for the bedroom.

Home lighting involves lamps, colors of interiors, cleaning, optical hygiene, amount and direction of light, but most of all, a realization of the vast difference between pleasant livable illumination and just lighting. Lighting and housing conditions can be improved tremendously if a little attention is given to the problem. The manufacturers of lamps, or the larger manufacturers of lighting devices, are ready to furnish service to increase the quality of illumination; and, finally, people should be impressed with the fact that better lighting is not necessarily more expensive.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

A REVIEW OF IMPORTANT DEVELOPMENTS IN THE SCIENCE OF CADASTRAL RESURVEYS AS EXECUTED BY THE UNITED STATES GOVERNMENT, WITH ETHICAL DISCUSSION THEREOF

Discussion*

By Howard Richards Farnsworth, Assoc. M. Am. Soc. C. E.†

Howard Richards Farnsworth,‡ Assoc. M. Am. Soc. C. E. (by letter).§—The character of the subject chosen, together with the definite intention on the part of the writer to present to the profession a résumé of those principles which official experience has proven will, when properly applied, assist the engineer in the solution of any problem of resurvey encountered, whatever the degree of complexity, has precluded any departure into the field of original Government surveys.

It may be stated, however, that the instrumental equipment and the field methods used for the projection and measurement of lines of both surveys and resurveys are much the same, but the problems encountered in the former, although difficult, are usually of a distinctly different nature—the element of private interest and vested rights not having such primary bearing. This reference, of course, does not include those original surveys executed of lands sometimes found along meanderable bodies of water, of islands, fictitious lakes, or other tracts, which it develops were erroneously omitted from the original township survey, nor does it include those other surveys, which the General Land Office alone is authorized and qualified under the law to execute, required for the identification of lands for purposes of evidence in suits or proceedings in behalf of the United States. This class of fragmentary work involves questions of status and classification as to survey and, thus, becomes closely allied to resurveys, inasmuch as the private rights involved are generally of paramount importance. The investigations and surveys which are now being executed in the bed and flood-plain of the Red River in connection with the Oklahoma-Texas boundary litigation, form an example of work of this class.

* Discussion of the paper by Howard Richards Farnsworth, Assoc. M. Am. Soc. C. E., continued from March, 1922, *Proceedings*.

† Author's closure.

‡ Member, Manual Board, General Land Office, Washington, D. C.

§ Received by the Secretary, April 4th, 1922.

Mr. Douglas* properly emphasizes the value of a correct reference of the basic system of the lines of any public works to the true meridian, as incidental to a finished return. In any long traverse such as a railroad, canal, or highway survey, where there is often no opportunity for closure, correct bearings of lines are especially desirable. In such cases the reported definite relation of each line to the meridian will provide the means by which to identify each line of the survey although only one point of the whole system may be known.

Attention has been called by Mr. Douglas to the ease with which the necessary co-ordinates of Polaris may be found in tabular form, for use in the identification of the star during the daylight hours. It might also be well to recall that precise tables of this character may be found in the "Nautical Almanac" published by the Naval Observatory.

A similar tabulation also appears in the 1921 edition of the "Ephemeris of the Sun and Polaris," to which pamphlet frequent reference was made by the writer in his paper. This table was formulated by the General Land Office to facilitate the determination of the latitude by an altitude observation of Polaris at any hour angle, the latitude of the station being determined by applying a primary and supplemental correction to the observed altitude of Polaris, properly corrected for refraction. The tabulation is concise and practical in its operation and the vertical angular values of Polaris above or below the pole for any mean time hour angle are readily taken from it. From a station of known latitude, the position in altitude of Polaris is thus easily determined. The position in azimuth of Polaris for a known latitude and a stated mean time hour angle and declination is readily apparent by reference to the table of azimuths of Polaris also to be found in this "Ephemeris". By the use of these two tables, the position of Polaris is easily found for any hour angle and latitude, from any station within the United States.

Mr. Hughes† exhibits much assurance in the revival of an old subject. The exposition of his method of traverse adjustment is made to the exclusion of all others, and it is championed with the courage of true conviction.

The earliest presentation of this "twist" method as far as the writer knows was made by Mr. F. Hodgeman,‡ in 1895. Mr. Hodgeman, however, guards the method properly by restricting its application to cases where it might definitely be known that the angular measurement and rhumb-line projections were perfectly accomplished and, therefore, that the whole error might theoretically be charged to defective measurement and the initial meridian determination. He explains,§ however, that in practice numerous additional errors occur from many causes and he then reiterates the first fundamental principle of balancing, a rule which has not ceased to be as sound in logic as it is unassailable, as follows:

"As the sum of the lengths of all the courses is to the length of each course, so is the total error to the error of that course."

* *Proceedings*, Am. Soc. C. E., January, 1922, p. 99.

† *Ibid.*, p. 100.

‡ "Manual of Land Surveying", pp. 78–81.

§ *Ibid*, pp. 120–121.

The method of traverse adjustment so vigorously championed by Mr. Hughes was known, discussed, and its limitations fully recognized many years ago by the Cadastral Engineering Service and has since been considered to be inapplicable to the reproduction of meander lines. In all other cases where this "twist" method has been brought to the writer's attention, its advocates have claimed for it only the limited application possible under a positive assumption as to the specific manner in which the errors in the survey were made, rather than the negation appearing in the expression, "in the absence of evidence to the contrary". As Mr. Hughes makes no attempt to confirm this negation, it follows that if there is no evidence in opposition to the specific assumption then there is also, by implication, certainly none in its favor, and the amazing conclusion is then reached that, in the absence of any knowledge whatever as to the contributory causes, all the error for this reason must be definitely assigned to the performance of certain functions and excluded from others.

According to the most elementary conception of the law of probability, if a lack of knowledge or evidence is admitted as to certain causes (the functions performed by instrument and chain), all elements contained therein must share responsibility in the known, combined effect (the closing error found). In the absence, therefore, of definite knowledge to the contrary, both instrument and chain in performing all their functions must be held to be mutually responsible for errors found, since each, independent of the other, measures one of the two polar co-ordinates necessary for the fixation of a definite point on the earth's surface. The combined effect of the instrumental errors in azimuth, angular deflection, and adjustment are chargeable with the same degree of inaccuracy as the combined effect of chain errors in leveling (or reduction to horizontal by clinometer), in the alignment by chainmen, and unit errors in the length of chain.

It should not be necessary to recall the fundamental principle that, when two or more independent measuring functions are performed to determine the co-ordinates of a point, the degree of accuracy with which that point is fixed substantially depends on the accuracy obtained by the least accurate of the various functions entering into the process. To perform the linear measurement in a definitely and materially less accurate manner than the angular measurement and projection of lines, would involve a loose and rash expenditure of time in the accomplishment of an accuracy which serves no purpose. A surveyor will avoid any ineffective refinements and, unconsciously, will regulate the operation of instrument and chain so that if either has a limit of accuracy materially different from the other, a needless waste of time will be avoided by no attempt at refinements materially inside the limits of the least accurate. This is certainly true as to the later survey or the resurvey which develops the error and, without doubt, is also true of the original survey. Naturally, then, a bold assumption as to the specific cause of error, that the discrepancy between the results of the original survey and the resurvey can "be attributed entirely to a difference in orientation, a difference in chain lengths, or a combination of both," and that, therefore, the error found was due entirely to erroneous orientation and chain lengths in both surveys, is particularly baseless and untenable.

Although it is recognized that the mechanical errors in chaining are compensative and subject to one law and that the unit errors in chain length and errors in alignment are cumulative and subject to a different law, the only permissible hypothesis as to the combined error of both chain and instrument is, that this combined error, which in its combined effect represents the result of all contributory causes, varies directly with the length of the line surveyed. When this conclusion is reached, the method of restoration follows as a matter of mathematical certainty and is that given in the paper. Any other hypothesis makes necessary an assumption of a definite knowledge as to the particular contributory causes which were previously held to be unknown. The question, then, is primarily one of hypothesis, for the proper method will follow as a secondary matter of accomplishment. For instance, in those cases where it is definitely known that the original surveyor inadvertently has confined all the error to the measurement and the initial azimuth, or perhaps, with a view to the ultimate application of this "twist" plan of restoration, has purposely done so, then, without doubt, the method set forth by Mr. Hughes follows with equal certainty.

In the case of a meander line, the angle-points of the traverse are established without monuments, except at the initial and terminal points, and the known error is that which results from the extension of the record bearings and lengths by a later and presumably more accurate survey from either existing terminal monument toward the other, or from both toward the particular angle-point to be recovered (see Figs. 9 and 10).* The direction and extent of the error thus developed is the same for all points along the traverse; that is, it must be considered from the record of a single later survey, regardless of its order of recorded progress, that it was extended from either existing terminal monument toward the other or from both toward any one of the angle-points, on the original record bearings and lengths; in which case, the error developed will be the same for all points.

Considering any one of the angle-points for the purpose of illustration, the recovery of its original position by a later survey must depend on and be influenced by all the existing evidence of such original position. The sum total of all this evidence is the two existing terminal monuments and the record of the original survey as to the courses and distances therefrom. The only logical manner whereby the influence of the known evidence can be properly exerted on the ultimate recovery of the point in question, is by extending from each existing monument the original record courses and distances until the angle-point is reached where, unless no error is developed, two separate points for the position thereof will be found (referred to hereinafter as temporary points, see Fig. 9*). If only one original terminal monument is assumed to be known, then the position reached for the angle-point from this monument should be adopted at once as the ultimate position thereof. Similarly, if the other of the terminal monuments is known, and the first one is lost, then the other of the two temporary points would be adopted with equal assurance as the final position. However, in the presence

* *Proceedings,* Am. Soc. C. E., November, 1921, p. 432.

of both terminal monuments and two separate temporary points, the true position for the restored angle-point must be such that it will be nearest to both temporary points indicated by the terminal monuments, or somewhere on a straight line between them. If the errors vary directly with the length of the line measured, this restored point will occupy such a position on this straight line, that it will divide the line into distances which are proportional to the length of the lines measured from each terminal monument.

By presenting the problem in this manner, the careful reader must see at once that each existing original monument and all the calls of the original record therefrom have been made to exert their proper influence in the recovery of the required angle-point, and he will realize that not only all legal requirements are fulfilled thereby, but the scientific requirements as well. The theory of non-concurrent parallel forces might be applied to this problem, or the principles involved in a determination of the "center of gravity", but the same resultant point would be reached. No one element whether it is the known monuments, the bearings, or the distances, can be regarded as evidence less competent than any other and to neglect any one of them arbitrarily and without reason, would be indefensible.

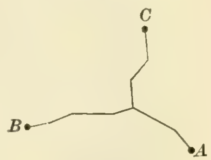

FIG. 14.

Consider, now, that, in the original record, a third existing corner monument had been connected by a traverse line to any one of the angle-points of the first traverse line, as shown in Fig. 14.

It would be interesting if Mr. Hughes would apply his method to the restoration of the angle-point common to both traverse lines. If each of the three existing corners was to share in the control of the restored angle-point, he would have no option, but to apply his method to the three pairs of corners separately, that is, first between Monuments A and B, second between Monuments A and C, and, third, between Monuments B and C. In this event, three different positions for the restored angle-point would result and he could not escape the necessity for consideration of a mean position of the three for his final position. A logical extension of this plan of restoration would also give two separate positions for every angle-point, other than the common point just referred to, in the tri-system. By determining a mean position for all such points and connecting them with right lines, what then would become of the proportional lengths of lines and the constant angle of twist?

In contrast with the inconsistency produced by the foregoing, the application of a method will be investigated, conceived in the assumption that all existing corners and all the calls of the original record are to share alike in a proportioned influence on the final position of the angle-point to be recovered.

Extend the lines on the record bearings and lengths from each existing monument (A, B and C), to each angle-point in the tri-system. This gives at once three temporary points for each angle-point of the system. Each of these points being weighed inversely as its distance from the corresponding existing monument, the mean position is found by applying the

principle of non-concurrent parallel forces as explained in the paper (see Figs. 8 and 9*). The application of this method is general, no matter how many existing monuments are considered as being connected with the point, the restored position of which is required, and no matter how complicated the system of the record survey may be. The results, in all cases, are logical and consistent.

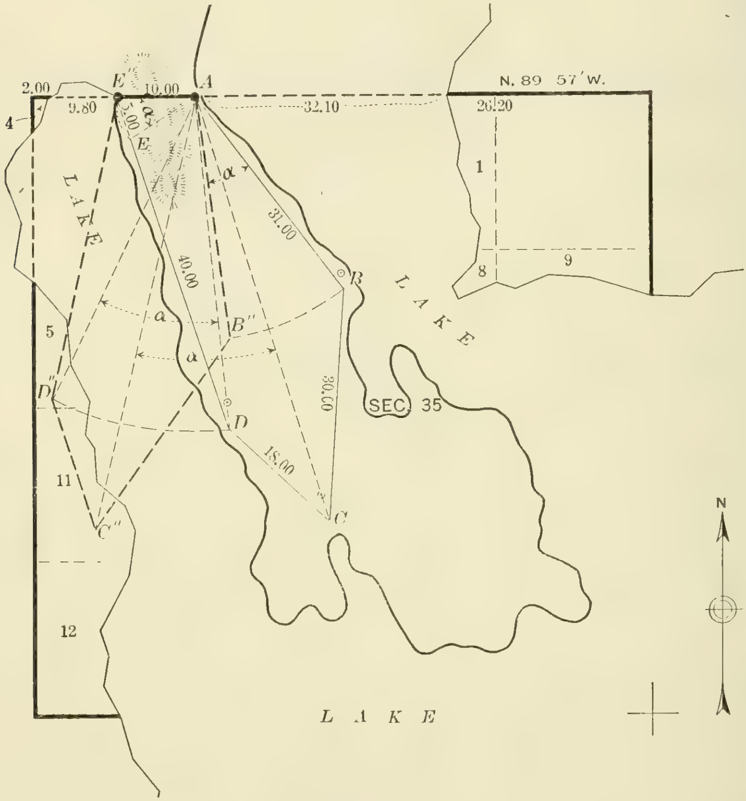

FIG. 15.

The absurdities which must be expected in any general application of the Hughes plan of restoration are only partly evident from his Fig. 13.† To make it more apparent, attention is invited to Fig. 15, which illustrates the restoration of the erroneous original meanders of a peninsula. This arrangement of the lines of the traverse is not unusual, and is often encountered also in the fixation of the boundaries of fictitious lakes. It will be observed that the assumed closing error is not excessive and may well be expected in view of the relatively long distance traversed. All the angle-points and terminal monuments have been designated in this diagram with letters corresponding to those assigned by Mr. Hughes in Fig. 13, in order that the restoration can be easily accomplished, following the plan as ex-

* *Proceedings*, Am. Soc. C. E., November, 1921, pp. 431–432.

† *Proceedings*, Am. Soc. C. E., January, 1922, p. 101.

plained by him. A fanciful position will immediately be occupied by the traverse system after its rigid orientation in azimuth, in fact, such resultant positions will sometimes reach into entirely different quadrants. The corresponding positions occupied by the angle-points when reproduced by the application of the only logical method are those indicated by the small circles.

It is believed that Mr. Hughes has either not read the paper as carefully as he should or else that he has allowed his judgment to be influenced more by the apparent geometrical elegance of the method he advocates than by a proper consideration of what is to be accomplished.

Mr. Tallman* furnishes conclusive evidence of the keen interest that he took in the work of the Cadastral Engineering Service throughout his incumbency as Commissioner of the General Land Office, and of his intimate knowledge of the general subject from the executive and legal point of view. As he has stated, it was largely during this period that previous experience developed into established principles and practice. He realized that, to a large extent, the adjudications of the Land Department and the operation of the various land laws must rest on and be influenced by the preliminary determinations of the cadastral engineer.

Effective safeguards for the elimination of errors in field observations, and practical suggestions for saving time in the resulting reduction operations, are frequently developed and verified through individual use. Such, apparently, is the case with Mr. Lightfoot, who has made valuable suggestions of methods he has used.† Where one finds real efficiency in the expenditure of time, with a due regard for accuracy, one will also find the origin of progressive ideas, and investigations looking to the development of new forms. Mr. Lightfoot's suggestion of the possible use of a tabulation of azimuths of the sun is interesting, and the writer would like to have had him pursue the investigation of such a tabulation further, in order to determine its practicality.

There is no one who deserves more studious attention in a discussion on the fact of cadastral surveys, their foundation in law, and their legislative development than Judge Proudfit, who has given a most interesting discussion of the subjects on which he has touched.‡ Particular attention has been given by him to the advantages immediately accruing to the Government in the abolition of the contract and the establishment of the direct method of execution. Mr. Patten and Mr. Le Baron have also stressed this point.§ When it is considered that the public domain is the people's most valuable heritage, it seems that the principle of conservation, as exemplified by proper facilities for accurate identification of the units of disposal, was applied to it none too soon. The Government's recent industrial experiences during the World War have furnished renewed and costly examples of what the public may continue to expect in its relations with an unscrupulous contractor. "Certainty in result" in this period of enlightenment surely should

* *Proceedings*, Am. Soc. C. E., February, 1922, p. 368.

† *Ibid*, p. 367.

‡ *Ibid*, p. 370.

§ *Proceedings*, Am. Soc. C. E., March, 1922, p. 703.

continue to be the primary object. The maintenance of a National body of civil engineers within the organization of the General Land Office to administer and execute the complicated work of Federal cadastral surveys and resurveys, as so aptly referred to by Judge Proudfit, is a natural pre-requisite to the attainment of certainty in results. The writer knows of few instances involving scientific endeavor, where the Government is obtaining satisfactory results through the medium of a contractor, even in the presence of the most rigorous safeguards.

It should be stated, in this connection, that those efforts toward perfection in results that this body of engineers is consistently maintaining, have been materially aided by the confidence and constructive co-operation of the members of the Board of Law Review of the General Land Office. The Cadastral Engineering Service is fortified in the knowledge that the conclusions and material prepared by its Manual Board for the first six chapters of the new "Manual of Surveying Instructions", stood with steady permanence the searching inquiry and critical judicial consideration of three such authorities on the jurisdiction and practice of the United States Land Department as Judges Samuel V. Proudfit, John McPhaul, and William H. Lewis, who participated in the closing conferences on these chapters before official approval. The familiar tradition involving the supposed indifference of the lawyer toward the engineer, certainly did not apply in the closing conference on the "Manual", recalled by Judge Proudfit, when he and his colleagues, the Commissioner; Mr. Frank M. Johnson, Supervisor of Surveys; and the Manual Board composed of Mr. Walter T. Paine, Chairman, associated with Messrs. Arthur D. Kidder, Thomas C. Havell, William H. Craigue, and Clinton G. Tudor, reached a unanimous agreement on the material prepared and presented by the Board for final consideration. When it is recalled that this work had previously received the endorsement of Mr. Charles L. Du Bois, for twenty-five years Chief of the Division of Surveys and Resurveys, its firm foundation in science and law will be duly appreciated, commensurate with the extent and quality of all the effort expended in its production.

Mr. Patten* has reviewed certain interesting events in connection with some of the resurvey projects in the State of Wyoming, and Mr. Le Baron* recalls the difficulties he encountered in the recovery of the obliterated evidence of the early surveys in Florida. His experience with the restoration of the lines of the five old Spanish land grants on which the City of Jacksonville is based, is illustrative of the difficulties encountered in the restoration of the irregular boundaries of some of these old grant lands, which are now often of great value. A recent example of a similar resurvey is the reproduction by the Cadastral Engineering Service of the boundaries of a tract, known as Rancho Potrero Chico, in Ts. 1 and 2 S., R. 11 W., S. B. M., California, in the suburbs of Los Angeles. In this case, clear identification of the boundaries of the granted lands had not been provided until the filing of the resurvey plat in 1920. As clear title had never been asserted to this tract, a United States patent covering it had still to issue on that date. The several claimants of record and parties in interest included eight individuals, the

* *Proceedings*, Am. Soc. C. E., March, 1922, p. 703.

State of California, and one oil corporation. The tract was reported to be worth \$1 000 per acre for agriculture and, in addition, to be covered with producing oil wells, thus making the property exceedingly valuable. Mr. Lightfoot will recall this interesting case, as he participated in the field work. The old archives of Spanish and Mexican origin, which are to be found in the files of the local offices of U. S. Surveyors General, include numerous interesting documents, many of which bear the signatures of the reigning monarchs and the rulers of those countries.

Mr. Le Baron's implication that an irrelation generally exists between the legal acreage as shown on official plats and actual conditions on the ground, and that there is always a corresponding loss of land by the Government, is somewhat misleading. As a matter of fact, it is found that the ordinary theories of probability are fully verified by the results of boundary retracements, other than those of limited scope, and that excesses and deficiencies in original measurements are developed with equal frequency. It might also be well to correct the statistical data which have been given as to the extent of completion of the subdivision of the public domain, and the present status of resurveys. The public land States include all the States, except the thirteen original States and Maine, Vermont, Kentucky, Tennessee, West Virginia, and Texas. The total land surface of the public land States is estimated at 1 442 200 320 acres, or more than three-fourths of the total area of the forty-eight States. The Territory of Alaska is estimated to cover 378 165 760 acres. On June 30th, 1921, about 168 000 000 acres of public land in the public land States had not yet been surveyed. In the Territory of Alaska, the area which has been surveyed is insignificant compared with the total area of the Territory. Retracements and resurveys have been and are now being executed in nearly all the Middle and Far Western States and in many Eastern-Southern States. As settlement and land values increase, the demand for Federal resurveys increases and often exceeds the available facilities for supply.

Land patents do not convey title primarily to a stipulated number of acres, but rather to certain designated units of disposal as fixed by the boundaries thereof. The area content is secondary and is that which is actually found to be embraced within the stated boundaries. Consequently, the writer is somewhat at a loss to understand what was intended by Mr. Le Baron in the suggestion that land patents had sometimes been issued which conveyed "no titles whatever." The nearest approach to this condition might be in a case of partial or total conflict of one claim with another, a situation which ordinarily must have been known to the affected entrymen, but had not been revealed to the General Land Office until the patents had been issued and were beyond recall. In such a case, the proprietary authority conveyed by the respective patents would be properly commensurate with the good faith of the entrymen during the progress of the entries toward the conferring of the titles, as each conflicting claimant would be fully aware of the equitable and relative rights of the other. If a just adjudication was made, neither claimant could rightfully consider himself to be injured.

The idea that patents might sometimes not convey title, even though not confronted by any adverse or superior claim, reminds one of the suggestion

sometimes advanced that when the record of the original survey, in a given locality, cannot be reconciled with the relative positions of the existing corners, or that when no physical evidence whatever of original monuments can be found, the inference is justified that the original surveyor did not run the lines as he stated in his field notes and, therefore, could not have built any corners; in which event, it is then maintained that the original corners cannot be recovered in a resurvey, or restored for the control of the boundaries of alienated lands.

Such a conclusion is based on entirely false premises. Resurveys do not attempt to reproduce that which once existed and is lost, but, rather, they reproduce that which the original record purports to exist. The physical corner monument itself is, of course, the best existing evidence of the position of the original survey as described in the record; however, if all the monuments had been originally established and were afterward lost, the same problem would confront one, as in the case where they were never established. In either case, one has the positions where the original record claims they were, and, therefore, it is not vital to the restoration whether or not the physical monuments were ever actually established, since, in both cases, all physical evidence thereof has been considered to be lost. The original survey, when official, is an enduring basis for disposal, and land titles are not to be invalidated at any time through the destruction of the corners. The survey is made enduring through the filing of the official field notes and plats. The proper interpretation of this original record, as referred to local conditions, for determining questions of good faith in location, makes necessary the application of the definition of good faith, such as is given on page 438 of the paper.*

A claimant is not necessarily involved in litigation in the adjudication of an area in conflict (see Plate VI).† In general, a conflict is subject to clearance by private mutual agreement, adjudication by a competent Court, or, when either party admits and asserts no proprietary right to such an area and voluntarily relinquishes all interest in the same, then, also, by the law providing for the amendment of entries or selections and re-issuance of patents, Section 2372, R. S., as amended by the Act approved February 24th, 1909 (35 Stat., 645). On a satisfactory showing by either party and reconveyance to the Government of unencumbered title covering the original units of disposal invaded by such conflicts, a re-described entry or patent will be issued by the General Land Office, reaffirming his interest in and title to the land, exclusive of the conflict. In these cases, the claimant is then allowed to take in lieu thereof, any equivalent area of vacant available land of appropriate class, which may be contiguous, or if none is adjoining, then to complete his homestead, selection, or other right, by taking any available equivalent area of vacant land, which may not be adjoining, the latter in the form of a supplementary entry or selection under the entry laws. The particular plan adopted for the clearance of any conflict depends on the attitude assumed by the parties in interest; however, in the end, each claimant should receive that to which he is entitled.

* *Proceedings*, Am. Soc. C. E., November, 1921.

† *Ibid*, p. 440.

The writer has reviewed in some detail the subject of conflicts, in the belief that the discussion will be of some value to engineers when they encounter these perplexing problems in the field. Concluding the discussion, there appears to be a general agreement that the subject of cadastral resurveys requires the most deliberate consideration by the Engineering Profession, in order that when attempts at restoration are made, the fixation of land boundaries and the delineation of private rights may be accomplished with finality.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

BUCKLING OF ELASTIC STRUCTURES

Discussion*

By H. M. Westergaard, Esq.†

H. M. Westergaard,‡ Esq. (by letter).§—The scope of the writer's investigation was defined so as to exclude the cases in which the deflections are large and those in which the stresses exceed the proportional limit. The first limitation excludes the consideration of the very slender structures the deformations of which have developed beyond the initial stage. The second limitation excludes the application of the method to the exact analysis of the heavier structures at the ultimate load, which can not be reached until the proportional limit has been exceeded. The phases of the subject thus excluded, are essential in a complete study of column action. For example, the action of short or medium-long columns can not be appreciated fully without taking into account the behavior of the material beyond the proportional limit; concerning this matter, reference is made to the works of Kármán, Southwell, and Salmon.||

By limiting the field, however, it became possible to develop an analysis which applies to structures of many shapes; and if the inevitable initial eccentricities are taken into account, as in Articles 24 to 26 of the paper,¶ this analysis will explain quite accurately the strength properties, not only of slender, but also of medium slender structures, for example, of medium slender columns. Rankine's formula is shown in this way to apply with rough approximation to the buckling of columns and of certain other structures (see the closing paragraph in Article 26).

Mr. Paaswell** has mentioned slender columns with deflections so large that Euler's theory must be replaced by a more general theory of the elastica. This

* Discussion of the paper by H. M. Westergaard, Esq., continued from February, 1922, *Proceedings*.

† Author's closure.

‡ Asst. Professor of Theoretical and Applied Mechanics, Univ. of Illinois, Urbana, Ill.

§ Received by the Secretary, April 24th, 1922.

|| For the works of Kármán and Southwell, see Bibliography, Section *B*, *Proceedings*, Am. Soc. C. E., November, 1921, p. 530; E. H. Salmon, "Columns" (Oxford Technical Publications, Lond., 1921), 279 pp. This work contains an extensive bibliography and account of previous work.

¶ *Proceedings*, Am. Soc. C. E., November, 1921, pp. 508–512.

** *Proceedings*, Am. Soc. C. E., January, 1922, p. 103.

case, strictly speaking, is outside the scope of the investigation, but the results of an exact analysis of it may be used to decide how large the deflections of a column may be before the deviations from Euler's theory become appreciable. A formula given by Schneider,* as a result of the exact analysis, is quoted: The end load on a hinged-ended column is:

$$P = \frac{\pi^2 E I}{L^2} \left(1 + \frac{1}{8} \left(\frac{\pi}{L} \right)^2 f^2 + \frac{19}{512} \left(\frac{\pi}{L} \right)^4 f^4 + \frac{29}{2048} \left(\frac{\pi}{L} \right)^6 f^6 + \ldots \right)$$

where L is the length measured along the elastic curve (slightly shortened by the axial force) and f is the maximum deflection. When $\frac{f}{L} = \frac{1}{10}$ the load, P, differs from Euler's value only by about 1.25%; that is, with a maximum deflection equal to as much as one-tenth of the length, Euler's theory still gives a close approximation.

In making applications of the analysis to the initial stages of flexure of the very slender structures, the possible influence of the weight of the structure must be carefully considered. For example, according to Euler's formula for hinged-ended columns, a steel blade, 0.025 in. by 1.5 by 36 in. (with $\frac{l}{r} = 5\,000$), would support an end load equal to 0.45 lb., but, as the blade weighs 0.38 lb., Euler's theory can not be applied unless the blade is placed in a horizontal position, on edge. Placed in a vertical position, with simple supports at the ends, the blade would buckle under the influence of its own weight when a small end load is added, but the elastic curve would not be a sine-curve as in Euler's theory; as long as the deflections remain small, there is a neutral or astatic equilibrium at a constant critical end load, but Euler's theory must be replaced by one in which the distributed weight is taken into consideration.

Mr. Paaswell refers to the actions of long, medium-long, and short columns as examples of astatic, heterostatic, and orthostatic actions, respectively. These illustrations are well chosen insofar as Euler's theory may be verified experimentally; for example, with hinge-ended steel columns in which the value of $\frac{l}{r}$ is greater than about 150; and insofar as the inevitable eccentric action of the medium length column may be interpreted, according to Articles 24 and 25 of the paper,† as special cases of heterostatic action; and insofar as the short column with $\frac{l}{r}$ less than about 50, does not buckle until the elastic limit has been exceeded.

Mr. Paaswell discusses a two-legged bent supporting a weight, W, at the center of the girder. A buckling of this bent in its own plane would be classified by the writer as a heterostatic action produced by a heterostatic load; for the load may be resolved into orthostatic and astatic components,

* Alois Schneider, "Zur Theorie der Knickfestigkeit", *Zeitschrift* des Oesterr. Ing.- und Arch. Vereines, Vol. 53 (1901), pp. 633–638, 649–653, in particular, p. 638.

† *Proceedings*, Am. Soc. C. E., November, 1921, pp. 508, 510.

as follows: The orthostatic component which, acting alone, produces bending stresses in columns and girder proportional to W, consists of the load, W, at the center of the girder and two upward forces, $\frac{W}{2}$, at the ends of the girder, and the astatic component which, acting alone, produces a neutral equilibrium with indefinite deflections of columns and girder at a critical value of W, consists of two downward forces, $\frac{W}{2}$, at the ends of the girder. The combined effects of the two components of the load may be computed by Formula (75) or Formula (102).* Unless the columns are slender, the critical values, Q_n, of W are likely to be so large as compared with the actual value, P, of W, that the terms containing the factors, $\frac{P}{Q_n - P}$, may be omitted in Formulas (75) and (102), and the action may be considered as being orthostatic. A buckling of the bent out of its plane under the influence of W would be an example of the mixed astatic action described in Article 23 of the paper,† if the buckling of the bent in its own plane still remains possible; if not, the buckling out of the plane becomes a pure astatic action, and the load, W, at the center of the girder becomes an astatic load.

The case analyzed by Mr. Halmos,‡ of the vertical cylinder supporting a vertical load and resisting an inside pressure, doubtless, is of interest and importance. The vertical load is an astatic load, because at a critical value it produces an astatic equilibrium with indefinitely increasing deflections. The writer would classify also the internal pressure as an astatic load; for at a critical negative value of this pressure, that is, at a certain outside pressure, pure buckling is produced. The combined vertical load and inside pressure, then, is an astatic load. The case is analogous to that of a simply supported rectangular slab buckling under the influence of a tension in the direction of one pair of sides and a compression in the direction of the other pair of sides; the diagrams in Fig. 7, in Article 10 of the paper,§ show that the presence of tension in one direction produces an increase of the value of the critical pressure in the other direction.

Mr. Godfrey‖ mentions the term, "stable neutral equilibrium", which was used by the writer. The term, perhaps, calls for some explanation. A reference to an equilibrium analogous to that of the column will serve this purpose. Consider a spherical ball resting on a horizontal table: The ball is in a neutral or astatic equilibrium because each position into which it may pass by rolling on the table is a position of equilibrium. This neutral equilibrium may be called stable insofar as there is no tendency for the ball to leave the table. Imagine a horizontal edge placed above the table. The ball may be balanced on this edge; and if it is guided by a pair of vertical boards on both sides of the edge, parallel to the edge, and barely touching the ball, the equilibrium

* *Proceedings*, Am. Soc. C. E., November, 1921, pp. 498, 504.

† *Ibid*, p. 506.

‡ *Proceedings*, Am. Soc. C. E., February, 1922, p. 373.

§ *Proceedings*, Am. Soc. C. E., November, 1921, p. 479.

‖ *Proceedings*, Am. Soc. C. E., February, 1922, p. 379.

obtained, again, is neutral, because it is maintained throughout a continuous range of positions, and it is stable, because the ball will not tend to leave the edge. If the vertical boards are removed, the equilibrium is still neutral, existing throughout the same range of positions, but it is unstable, for the least tilting force would make the ball fall on the table; ultimately, then, the ball would revert to the original state of neutral equilibrium on the table.

Consider a slender hinged-ended column: If the ends are forced to approach each other by a small definite distance, the column will buckle into a sine-curve with one half-wave; at a small change of this distance, the maximum deflection will change, but the elastic curve remains a sine-curve with one half-wave, and the required end load remains the same, equal to Euler's value; the equilibrium is neutral and stable, and is analogous to the equilibrium of the ball on the table. Let the column be simply supported at the center; it will buckle, then, into a sine-curve with two half-waves; the neutral equilibrium obtained is analogous to that of the ball on the edge between the two boards; the reactions at the central support are of the same nature as the reactions of the boards on the ball. If the central support is removed, the column will still be in a neutral equilibrium in the same range of positions; but a small transverse force will disturb this equilibrium, which, therefore, is unstable, like the equilibrium of the ball on the edge when the boards have been removed. If the ends of the column are kept at a constant distance, the elastic curve will revert to the original sine-curve with one-half wave; this reversion to the stable type is analogous to the fall of the ball from the edge to the table. The set of neutral equilibria at the higher astatic loads, may be represented in the analogy by a set of horizontal edges, one above the other.

Concerning the matter mentioned by Mr. Godfrey, of the stability of a thin circular cylinder or ring subjected to outside pressure, reference is made to Part *C* in Mr. Halmos' discussion* and to the papers listed in Section *G* in the Bibliography,† particularly to Goupil's analysis. In this connection, an article by Hencky,‡ which appeared recently, may be mentioned; it deals with the stability of a circular ring against warping.

Concerning the coefficients of moments in slabs mentioned by Mr. Godfrey, reference is made to a recent paper on "Moments and Stresses in Slabs", by W. A. Slater, M. Am. Soc. C. E., and the writer.§ The coefficient, 0.077, refers not to a slab, but to a double system of crossing-beams, as was discussed at the end of Article 31 (Formulas (158) and (159)) of the paper.‖

The writer agrees with Mr. Godfrey concerning the importance of knowing the factor of safety and understanding its significance under the various conditions. As emphasized previously, the ultimate load, and, through it, the factor of safety, are dependent, in the case of medium slender and heavy structures, on the conditions after the proportional limit of the material has been exceeded. Further investigations, following the course indicated by Kármán and Southwell, are needed in this field.

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* *Proceedings,* Am. Soc. C. E., February, 1922, p. 378.

† *Ibid,* November, 1921, p. 532.

‡ "Kippsicherheit und Achterbildung an geschlossenen Kreisringen". *Zeitschrift für angewandte Mathematik und Mechanik*, v. 1 (1921), pp. 451–455.

§ *Proceedings,* Am. Concrete Inst. (1921), pp. 431 and 438.

‖ *Proceedings,* Am. Soc. C. E., November, 1921, p. 527.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE AREA OF WATER SURFACE AS A CONTROLLING FACTOR IN THE CONDITION OF POLLUTED HARBOR WATERS

Discussion*

By Messrs. George A. Soper and H. W. Clark.

George A. Soper,† M. Am. Soc. C. E. (by letter).‡—The writer is interested in papers which deal with the pollution of New York Harbor, for it is only through the discussion of this greatest of all practical sewage problems that engineers can come to understand the conditions which exist, and form an opinion as to the character of the works which are required to dispose properly of the sewage of the Metropolitan District. For a subject of such great importance to New York and, in fact, to the whole country, there is a singular lack of understanding of the question, and this applies to the general public and to the Engineering Profession alike.

An obstacle to the proper grasp of the elements of the problem lies in the tendency to regard the harbor somewhat as a laboratory vessel or tank concerning which it is easy and safe to make general observations. As a matter of fact, the sanitary protection of the waterways in the Metropolitan District probably offers the most diverse and complicated series of engineering, chemical, and biological problems that has ever been presented. After an experience of eleven years of official connection with these problems, the writer has come to look on dogmatic, unqualified, and sweeping assertions concerning them with considerable impatience.

The author seems not to be one who is willing to confine himself to the quick and easy method of argument, but has taken data from the reports of the Metropolitan Sewerage Commission and, with information of his own collecting, has sought to advance the existing knowledge of the subject by calculations of the sources of oxygen, which can be utilized in finally disposing of the sewage. The fact that the writer cannot fully agree with him in his conclusions, does not destroy his sense of the value of the paper.

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* Discussion of the paper by Richard H. Gould, Assoc. M. Am. Soc. C. E., continued from April, 1922, *Proceedings*.

† Cons. Engr., New York City.

‡ Received by the Secretary, April 22d, 1922.

That large quantities of oxygen are absorbed from the atmosphere has long been recognized, but no one has gone as far as the author in attributing such a generous share of the renewal to this source. If "the dissolved oxygen in the waters will be depleted until the rate of absorption from the air equals the rate of oxygen demand of the fermenting organic matter", the question naturally arises, how is it that the oxygen content throughout the harbor is falling lower and lower, until, in some of the main divisions, it has recently been reported as absent?

In spite of its many excellences, the paper contains ambiguities and inconsistencies of statement which leave some of the author's views obscure. If these defects were remedied, it is quite possible that the writer would see no reason to differ with him.

H. W. CLARK,* ESQ. (by letter).†—There can be little criticism of the conclusion drawn by Mr. Gould in regard to surface absorption of oxygen, although the writer believes that the clean tidal water saturated with oxygen, or nearly so, coming into polluted harbors is, perhaps, of greater importance than Mr. Gould's figures seem to show. There is a tremendous absorption of oxygen by water when exposed to the air, and especially so when it is ruffled by wind. In the report of the Massachusetts State Board of Health for 1891, the greater absorption of oxygen in water and its absorption to greater depth due to wind action was discussed by the late Dr. Thomas M. Drown, in an article entitled "Amount of Dissolved Oxygen Contained in Waters of Ponds and Reservoirs at Different Depths."

Work on this subject has been done by the writer from time to time, and a discussion in regard to the absorption of oxygen and the purification of sewage due to such absorption, was given in his report to the Charles River Dam Committee in 1902, together with various experiments to show the purification of polluted water by oxygen absorption. Certain of these experiments with fresh water (90% saturated with oxygen), to which was added, in different bottles 1, 3, 5, and 10% of strong sewage, showed the exhaustion of oxygen and the development of odors under closed conditions, whereas with surface exposure, the absorption of oxygen to replace that used in purification, was very marked. In this report, after calling attention to the changes occurring after the Charles River Tidal Estuary would be turned into a fresh-water basin, preventing the entrance of sea water saturated, or nearly so, with oxygen, and calling attention to the volume of sewage that would enter it daily, the following statement was made:

"In this last connection, it must be understood that under any condition which can exist in the basin the surface water will be continually changing. The basin lies so that it is exposed to the unrestricted sweep of the prevailing summer wind and even at times of light breeze the change will be quite rapid and hence each day there is a chance for much oxygen to be taken up by the water of the basin in this way."

Mr. E. A. Letts‡ has stated that Dr. Adeney found that ten days were required to saturate with oxygen a sheet of water with a temperature of 15°

* Chf. Chemist, Massachusetts Dept. of Public Health, Boston, Mass.

† Received by the Secretary, April 28th. 1922.

‡ *Journal*, Royal Sanitary Inst., Vol. XXXIII, No. 1.

cent., 6 ft. in depth, and deprived of all atmospheric gases. In experiments made by the writer in 1912, and described in the report of the State Board of Health for that year, it was shown that quiet water in a body only 7 in. in depth required seven days to increase from 0.38 parts per 100 000 dissolved oxygen to 0.94 parts per 100 000, or saturation at the temperature of the experiment. The increase was at the rate of 0.08 parts per day. When, however, this shallow vessel contained a small fish, an amount of oxygen equal to 0.26 parts per day was absorbed, or the amount consumed by the fish daily, as had been previously proved. This experiment covered a period of thirty-four days. In this case, undoubtedly the surface of the water was more or less ruffled by the movements of this fish. Recent experiments by the writer have also seemed to show that, as Adeney has stated, dissolved oxygen streams from the top to the bottom of a liquid. To prove this, a glass cylinder, 10 in. in diameter and 3 ft. deep, was filled with water polluted to such an extent that dissolved oxygen failed to be present. Methylene blue added to this water was decolorized at first, owing to the absence of oxgyen, but as oxygen was absorbed, streams of the blue dye were shown throughout the depth of the water, thus indicating the penetration of the oxygen from the surface downward. This experiment was with an absolutely quiet surface.

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PAPERS AND DISCUSSIONS

TENTATIVE SPECIFICATIONS FOR STEEL RAILWAY BRIDGES

SUBMITTED AS A PROGRESS REPORT OF THE SPECIAL COMMITTEE ON SPECIFICATIONS FOR BRIDGE DESIGN AND CONSTRUCTION

Discussion*

BY J. W. SPILLER, ESQ.

J. W. SPILLER, ESQ.† (by letter).‡—A Sub-Committee of the British Engineering Standards Association, of which the writer is a member, is, at present, drafting a specification similar to the Tentative Specification presented by the Committee. In the first place, this Sub-Committee prepared a specification covering "Materials and Workmanship", and then divided into panels to deal with: (*a*) Loads; (*b*) Stress Units; and (*c*) Details of Design and Construction. The writer was placed on the panel dealing with "Details of Design and Construction".

The writer does not propose to offer any observations on that part of the Tentative Specification which deals with these subjects, but will confine his comments to the questions of material, workmanship, and the details of Design and Construction. The arrangement of Sections and Articles appears to be generally satisfactory, but perhaps an even better sequence would be obtained if "Section 9.—Materials" followed immediately after "Section C", and "Section 11.—Weighing and Shipping", followed "Section 13.—Mill and Shop Inspection."

Article 204.—In this Article the "nominal diameter" of a rivet is referred to. In Great Britain, there is a difference of opinion, particularly between bridge builders and shipbuilders, as to the exact point on the tapered shank where the diameter should be measured. It might be well, therefore, to define clearly what is the "nominal diameter".

* Continued from April, 1922, *Proceedings*.

† Deputy Chf. Engr. for Design, Crown Agts. for the Colonies, London, England.

‡ Received by the Secretary, April 15th, 1922.

Article 308.—It is stipulated in this Article that "connections shall have a strength at least equal to that of the members connected, regardless of the computed strength". This appears to require some qualification in the case of members which are in compression where the strength of the member will depend on the value of the ratio, $\frac{l}{r}$, whereas the strength of the connections will be independent of this ratio.

Article 309.—Limiting Thickness of Metal.—Some differentiation might be made perhaps between plates, etc., which are accessible for painting on one side and those which are accessible for painting on both sides.

Article 310.—Pitch of Rivets.—The maximum pitch proposed appears to be too great to insure that no corrosion will take place between the parts connected.

Article 324.—Splices.—The gross area of the splice material proposed, namely, 50% of the gross area of the smaller member, does not appear to the writer to be sufficient. Articles 308 and 324 appear to be inconsistent to some extent.

Articles 610 and 611.—Stiffeners.—These Articles do not permit the use of T-beams which make a suitable and economical form of stiffener for small spans.

Article 703.—Camber.—The writer is inclined to think that it is better practice to make the camber equal to the deflection produced by both dead and live load. If, then, one-half the camber due to live load is taken out by notching the sleepers, the level of the rails at the span center will be lower than that at the support by an amount equal to one-half the deflection due to live load when the bridge is loaded and will be higher by a similar amount when the bridge is not loaded.

Articles 1004 to 1007.—Punching.—The limits of thickness for punching appear to be on the high side for first-class workmanship.

Article 1016.—Web-Plates.—The large clearance allowed between ends of web-plates, namely, $\frac{3}{8}$ in., does not appear to be quite consistent with first-class workmanship.

No reference is made in the Specification to the supply of service bolts which should be provided by the bridge fabricator whether or not his contract includes erection at site.

The writer should like to add that the foregoing comments are not advanced in a spirit of criticism. The Committee has submitted a valuable specification and it is with considerable diffidence that the writer has ventured to draw attention to a few small matters of detail which appear to differ from what would be considered first-class practice in Great Britain.

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PAPERS AND DISCUSSIONS

SOME NOTES ON THE LOCATION AND CONSTRUCTION OF LOCKS AND MOVABLE DAMS ON THE OHIO RIVER, WITH PARTICULAR REFERENCE TO OHIO RIVER DAM NO. 18

Discussion*

BY MESSRS. C. I. GRIMM, B. F. THOMAS, MALCOLM ELLIOTT, FREDERICK B. DUIS, AND W. H. MCALPINE.

C. I. GRIMM,† ASSOC. M. AM. SOC. C. E. (by letter).‡—The author has discussed to a greater or less extent all the engineering features that pertain to the construction of locks and dams on the Ohio River, and particularly to Dam No. 18. This discussion, therefore, will be confined to elaboration on a few subjects which have been of interest to the writer in studying locations and preparing designs and estimates for a considerable number of locks and dams and which are covered rather briefly by the author. These subjects are: (*a*) Foundations; (*b*) weirs; and (*c*) lock-gates.

(*a*).—*Foundations.*—For the first thirty-one dams, it has generally been practicable to build on rock foundation, but below Dam No. 31, such foundations are exceptional. Where rock is not available, dams are supported on wooden piles, generally 30 ft. long, and the present practice is to place a row of interlocking steel sheet-piles, 40 ft. long, under the up-stream edge of the foundation. For the earlier dams, these sheet-piles are of wood, 25 ft. long, and of tongue-and-groove construction. When built on piles, the foundations are protected below the dam by a rock-filled timber crib and an apron of heavy rip-rap.

Although it might appear that for these low lifts, not exceeding 9 ft., the importance of a rock foundation is not significant, this is not true on account of the scour below the weir, which is so extensive that the stability of dams built on pile foundations is endangered to some extent, thus making it necessary to take soundings periodically and place additional rip-rap from time to

* Discussion of the paper by William M. Hall, M. Am. Soc. C. E., continued from April, 1922, *Proceedings*.

† Asst. Engr., U. S. Engr. Office, Cincinnati, Ohio.

‡ Received by the Secretary, April 6th, 1922.

time. This is especially true in the lower stretch of the river, where the underlying material is sand or contains a large percentage of sand. Where rock foundations have been found, the rock has generally been at such an elevation that the dams were constructed economically by excavating inside an open box coffer-dam, such as was used for Dam No. 18, and placing the concrete foundations on a cleared rock surface. Such construction has been carried to various depths up to a maximum of about 20 ft. below low water. If rock is at a depth of 20 ft. or more below low water, a pile foundation will cost less than one on rock. The advantages of building on rock, however, warrant some additional cost. It has not usually been necessary to give this matter careful consideration, because where the depth of rock was not less than 20 ft., it was so much in excess of this that the cost of building on it was readily seen to be excessive. In the case of Dam No. 32, which is now being designed, the depth of rock is about 23 ft. below low water, and plans for building this dam on rock are being considered. It is proposed to utilize a box coffer-dam of the usual type and inside of this coffer-dam to sink open concrete caissons from the river bed to rock, a distance of about 12 ft. These open caissons, which are comparatively small units, will then be pumped out one at a time and filled with concrete. It is estimated that this construction will cost little more than a pile foundation. At Dam No. 23, where the underlying rock was about 15 ft. below low water, the Dravo Contracting Company constructed the dam (840 ft. long from the lock to the bear-trap) inside of coffer-dams about 45 ft. wide and 160 ft. long, the walls being of a single row of Lackawanna steel piling braced across the 45-ft. width. This work was accomplished speedily and economically.

Ohio River dams constructed on sand and gravel, with a cut-off wall of 40-ft. interlocking steel piles, have a length of "creep" equal to about ten times the maximum head, and where 25-ft. wooden piles are used, it is about eight times the maximum head. Experience has shown that in practice the wooden sheet-piles, even though carefully driven, are not sufficiently tight to form an effective cut-off. Their use has been limited to the upper part of the river where foundations consist of rather coarse gravel and sand, and they are not regarded as adequate for the more sandy foundations of the lower river. No evidence of "boils" under any dams that are in service has appeared, and it is believed that these dams have adequate protection from this danger, unless they are undermined by scouring action below the weirs, which action must be carefully guarded against by proper construction and periodical inspection.

(*b*).—*Weirs.*—The weirs for Dam No. 18 and the earlier Ohio River dams were designed to pass a flow equal to the open-river flow at a stage of from 9 to 10 ft. The apparent advantage of having a large weir capacity is that it lessens the extent of maneuvering the wickets of the navigable pass, but this is an advantage only in case the weir can be maneuvered with greater ease or greater speed than the navigable pass. However, in practice, no more suitable means of raising the wickets of the weir has developed than the maneuver boat. Discharges equal to a 12-ft. stage are passed through the weir and a part of the lowered dam, since the dams are partly raised at stages greater than 9 ft. and are not entirely lowered when the capacity of the weir

is reached, unless it is evident that the approaching rise will be high enough to submerge the pass wickets the tops of which are generally about 13 ft. above low water. In practice, a part of the navigable pass, therefore, is used as a weir and the capacity of the weir including the lowered part of the navigable pass is equal to an open-river stage of about 12 ft. As stated by the author, the operation of the Chanoine weir from the service bridge has generally been discontinued, and on account of their inaccessibility to the maneuver boat which operates the movable dam, these weirs are not used. Many of the dams now in operation have, therefore, a usable weir of two 91-ft. bear-traps only. At Dam No. 29, for example, the capacity of the bear-traps is about equal to a 7-ft. open-river stage. This dam is maneuvered successfully to pass any stage up to 12 ft., by lowering a part of the navigable pass. It is necessary, of course, to raise the pass wickets against greater heads than would prevail if the Chanoine weir was in use, and it is rather difficult to raise the last wickets of the pass. In view of the foregoing, it is not regarded as necessary to provide, in addition to the navigable pass, a weir capacity sufficient to discharge a 9-ft. open-river flow and as the cost of the dam is decreased by decreasing the length of the weir, this factor should be given proper weight in the design of weirs.

The bear-trap is generally recognized by those who have had experience on the Ohio River, as the most satisfactory regulating weir that has been devised for this stream, by reason of the fact that it may be operated with greater ease, greater safety, greater speed, and more certainty than any other type. However, in determining the extent of its use, consideration must be given to its first cost, which is high in comparison with that of wicket weirs. Two 91-ft. bear-traps with their piers occupy 220 lin. ft. of dam and will cost more than double the same length of wicket weir. The cost per foot of a weir of Chanoine or Bebout wickets is considerably more than that of a fixed dam, and where a part of this weir may be replaced by a fixed dam, by using some of the navigable pass as a regulating weir, a saving in cost will be effected. Economic considerations, therefore, should limit the weir lengths to those required by the following conditions:

(1) There must be a sufficient area of movable dam and weir so that, when they are lowered, the velocity in the contracted channel will not interfere with navigation.

(2) The weir area must be sufficient so that the pass wickets need not be maneuvered against a head greater than 5 ft.

In the recent designs for Dams Nos. 34, 36, and 38, the weirs have been given considerable attention, and the completed plans have some features which differ from Dam No. 18, or any other Ohio River dams. In these designs, two 91-ft. bear-traps, with the sill 15 ft. below the upper pool, are provided and also a weir, 100 ft. long, of Chanoine wickets, with the sill 11 ft. below the upper pool. The Chanoine weir is provided with a tripping bar for lowering and this weir is placed between the bear-trap and the navigable pass so that it may be maneuvered by the boat which maneuvers the navigable pass, as the weir wickets will be raised by the maneuver boat. The tripping device is similar to that which has been in successful operation on weirs of the Big

Sandy River and the mechanism for operating the tripping bar is on the bear-trap pier.

The weirs for these dams, exclusive of the navigable pass, will discharge a quantity about equal to an 8-ft. open-river stage when pools are at normal height above the dams. The height of the upper pool above low water is as follows: Dam No. 34, 13 ft.; Dam No. 36, 13.7 ft.; and Dam No. 38, 11.6 ft. As the discharge through the weirs will raise the water below to an 8-ft. stage, the maximum heads on the pass wickets, when the weirs are open and the upper pools normal, will be as follows, without allowance for leakage between the pass wickets: Dam No. 34, 5 ft.; Dam No. 36, 5.7 ft.; and Dam No. 38, 3.6 ft. The leakage between the pass wickets will further reduce this head, as will also the raising of the dams below. Furthermore, the raising of the pass wickets is usually completed before the upper pool has filled, although this does not apply when raising only a part of the dam that has been lowered to pass a discharge slightly greater than the weir can pass. In view of these considerations, it appears that the pass wickets, which are used for pool regulation at these dams, will generally be maneuvered against heads of less than 5 ft. and that a weir capacity equal to an 8-ft. open-river discharge is ample for these dams. The space between the bear-trap and the abutment is closed, by a fixed concrete dam having a minimum length of 252 ft. at Dam No. 36. This places the weirs far enough from the bank that no appreciable scouring of the bank is anticipated. On account of the severe scouring action that occurs below the bear-traps, they should be placed some distance from the river bank if the width of the river at the dam permits it.

(*c*).—*Lock-Gates.*—The lock-gates of Dam No. 18 and of all other Ohio River locks constructed prior to 1916, are of the rolling type. These gates move from recesses back of the land wall across the lock chamber, closing the ends of the locks and forming a water-tight bulkhead. The gate at the upper end of the lock is 17.4 ft. high and that at the lower end 22 ft. high, or somewhat less, depending on the lift. Each gate is mounted on ten pairs of standard car wheels which roll on a steel track.

This type of gate, although somewhat unusual, was selected on account of the limited height of the gates and the great width of the lock, which are far from ideal conditions for the more usual type of mitering gates. The rolling gates, although they have occasioned some minor difficulty from broken wheels and tracks, in general, have operated satisfactorily in the upper river. In the lower river, however, where deposits of mud and sand are extensive during high water, the recesses, unless closely sealed, become so filled with deposits that the cleaning of them involves considerable expense as well as possible interruption to navigation before the lock can be placed in operation. In view of the difficulty and uncertainty of sealing the recesses, the rolling gates were not regarded as satisfactory for the lower river and, in 1914, the Ohio River Board of Engineer Officers adopted a design for mitering gates. As previously stated, the great width of the lock and the limited height of the gates are conditions which are not favorable for mitering gates, but by the use of vertically framed gates, well braced, and with strong bearings and anchorages, a satisfactory design has been effected. These gates have been

installed at ten locks and, except for a few minor defects in details, which were readily corrected, have operated satisfactorily, and have been found readily adjustable for any wear, deflection, or warping that has occurred. The recesses for the rolling gates are readily coffered by means of a timber bulkhead and pumped out when repairs or painting is necessary, whereas for the mitering gates, it is either necessary to install a considerable coffer-dam and pump out the lock or lift the gates out by derrick boats. It appears that, in the case of the mitering gates, the latter method and the carrying of spare gates will become necessary if navigation becomes so extensive that it cannot be interrupted except for short periods.

Considerable study has been given to the comparison of first cost of Ohio River locks with rolling or mitering gates, and it has been found that, in general, neither has any marked advantage in this respect when operating machinery and power plant are considered. If the lock is located at a steep rocky bank, the rolling gates are at a disadvantage as it is either necessary to make costly excavation for the recesses or move the lock out from the bank and this increases the cost on account of the filling and paving required back of the land wall. Except for special cases, the first cost is not a consideration and the advantages of operation, making repairs, replacements, etc., although somewhat balanced for present conditions, would be in favor of mitering gates, if navigation becomes as extensive as is contemplated and hoped for when the improvement of the river is completed.

B. F. THOMAS,* M. AM. SOC. C. E. (by letter).†—In recent study of the design of dams on the Ohio River, in the vicinity of Cincinnati, Ohio, considerable discussion has arisen as to several points on which no great emphasis (at least in print) has heretofore been placed. Some of these points will be enumerated by the writer in this discussion. The dams have generally been provided with two bear-trap weirs, a pier separating the first trap (counting from the lock) from the navigation pass. The pass, which is closed by Chanoine wickets, is usually 700 ft. wide, and each bear-trap is 91 ft. wide. Following the bear-traps, there has been provided, at a number of dams, a weir of Chanoine wickets with a sill considerably higher than that of the pass. In recent discussions, it has been suggested that the Chanoine weir be placed next to the pass and that there be no pier to mark the change in sill elevation. It has also been proposed to lower the weir wickets with a tripping bar similar to the method used on Big Sandy River, and on the twenty-seven dams of the Belgian Meuse, the maneuver boat to be used only for raising this section of the dam, but to be used both in raising and lowering the pass wickets, as at present.

The writer would recommend for dams on this part of the Ohio River, the following arrangement: Chanoine wicket pass, 700 ft. long; pier, 12 ft. wide; two bear-traps, each 91 ft. wide; pier, 12 ft. wide between traps; and fixed weir, 181 ft. long, or sufficient to reach the shore abutment.

In case greater weir capacity is desirable, or necessary, he would recommend that a Chanoine wicket weir with tripping bar be placed next to the

* U. S. Asst. Engr., Catlettsburg, Ky.

† Received by the Secretary, April 12th, 1922.

pass, with the pier between it and the pass, the length of the fixed weir being reduced accordingly. Although he does not consider a pier at the end of the pass an absolute necessity, in case a Chanoine weir with a sill considerably higher than that of pass is put in, still it is a desirable arrangement, and it is believed that there is practical unanimity among navigators and river men in general that such a guide for their movement at dams should be provided. The currents are uncertain at the dams and a tow is liable to be carried against the weir and wrecked. The use of a buoy or especially constructed wicket for defining the point of change in elevation of the sill, it is believed, would be unsatisfactory; in fact, it is not believed that a buoy could be maintained in periods of drift and ice.

It is believed that with a sill about 4 ft. higher than that of the pass, little, if any, trouble from gravel interfering with the tripping bar, would be experienced. However, its mechanism and the bar itself should be designed with sufficient strength and power to crush such obstruction to the movement of the bar as might interfere therewith. The fact that at the time the bar is in use, the water is surging at great velocity through the spaces made by the falling wickets would insure, it is thought, the cleaning of the deposit from around it.

From experience at one dam in the upper river, which has no bear-trap, and from similar experience at dams having only one bear-trap, as reported by the engineer in charge, it would seem unwise to build a new dam with only one trap. The regulation of pool levels where navigation exists is a most important feature in the Ohio River system, and it has been proven that no other device thus far tried or proposed will equal the bear-trap as a regulator. With it, regulation is certain, operation easy and speedy, action reliable, and its work is generally satisfactory; its upkeep is not expensive, and will become less as its working becomes better understood by the engineers in charge.

After much study the writer has come to the conclusion that it would be a serious mistake to substitute any kind of weir heretofore proposed for the bear-trap. The following memoranda are submitted for consideration. As to a pier between a pass and a bear-trap or between a pass and a weir of any type:

(*a*).—The junction of the two sills at different elevations would without a pier form an obstruction to navigation, which cannot be seen by day nor lighted at night.

(*b*).—It furnishes a convenient and firm mooring for the maneuver boat and its lines, during maneuvers, and if its up-stream end is placed flush with the up-stream face of the wickets, it would offer no impediment to the movement of the boat.

(*c*).—It is a guide to navigation; without it, the cross-currents may cause a tow to swing over against it at stages when the weir sill would have insufficient depth for tow.

(*d*).—Navigation has always had this sort of guide to the passage of the dam and would, it is believed, complain greatly and feel uncertain without it.

(*e*).—The experience of the engineers in the Wheeling District indicates that where there are two traps, the maneuver boat was sent out for regulating purposes only five times in a season, while with one trap it went out thirty-six times, and with no trap eighty-nine times. This seems a most convincing argument in favor of two bear-traps. With the large number of tributaries coming in below the dams in the Wheeling District, the writer believes it would be very unwise to put in a dam with less than two traps, especially as the quantity of drift and number of quick, unannounced freshets is great.

MALCOLM ELLIOTT,* M. AM. SOC. C. E. (by letter).†—Although the time has not yet arrived for a definite decision as to whether the improvements of the Ohio River and their large cost have been justified to the taxpayers, it would seem to be proper, in discussing this paper, to survey the accomplishments to date, the status of water transportation on the Ohio River, the cost of the work, and the prospects for the future.

Thirty-six of the Ohio River dams are now ready for operation. The series is complete from Nos. 1 to 26, inclusive, Dam No. 26 being just below Point Pleasant, W. Va. (Fig. 1).‡ Dam No. 27 is about 80% completed and will be ready for operation during the season of 1923, making the series complete from Nos. 1 to 29, inclusive. Below Dam No. 29, Dams Nos. 31, 33, 35, 37, 39, 41, 43, and 48 are in operation, thus making it possible to fill every alternate pool as far as Dam No. 43, and greatly improving the condition over the open channel as it existed before the construction of the dams. All the even numbered dams intervening, to include Dam No. 44, are under construction, and their completion may be expected within a reasonable time, thus furnishing slack-water navigation from Pittsburgh, Pa., to Leavenworth, Ind., a distance of about 650 miles—the upper two-thirds of the length of the river. Dam No. 48 is the only one below Leavenworth ready for operation.

Below Leavenworth, the river conditions become less favorable to the construction of locks and dams. The bottom is less stable than in the upper reaches, and it is feared that much trouble will be had with deposits of sand, which will make difficult the operation of the dams and lock-gates. The abandonment of the slack-water system in favor of open-channel regulation by dredging and training works in the lower part of the river, has been considered, but it is not known whether any decision has been reached. A little experience at Dam No. 48, near Evansville, Ind., recently completed, will furnish information as to the feasibility of constructing more locks and dams in that section of the river.

The author gives the tonnage for 1894, 1916, and 1917 only. To supplement these figures, it may be said that the greatest tonnage in any year was 14 054 000 in 1900, the smallest, since 1892, was 4 599 000 in 1917, and the tonnage for 1920, the last year reported, was 9 382 000, hauled an average distance of 126 miles, making 1 184 000 000 ton-miles. It will be noted that the greatest tonnage was carried before the slack-water improvements were even begun and that now, with these improvements more than two-thirds completed,

* Maj., Corps of Engrs., U. S. A., Wheeling, W. Va.

† Received by the Secretary, April 25th, 1922.

‡ *Proceedings*, Am. Soc. C. E., January, 1922, p. 5.

it is less than it was without the dams. Therefore, the question might well be asked, would it not have been better to have made no expenditures? This question and some of the factors which have influenced commerce on the Ohio River will be discussed subsequently. First, however, an estimate is given of the costs of the work to June 30th, 1921, the latest date for which published figures are available.

The following figures are compiled from the report of the Chief of Engineers, U. S. Army, for the fiscal year ended June 30th, 1921:

Total amount expended on new work on all projects to June 30th, 1921, including the purchase of the Louisville and Portland Canal, improvements of Pittsburgh Harbor, snagging and open-channel work........................	$85 746 412
Total amount expended on maintenance, operation, and care to June 30th, 1921............................	13 268 705
Total of all money spent on Ohio River to June 30th, 1921.	$99 015 117
Expended for operating and care of locks and dams for year 1920-21	$1 061 973
Maintenance of dredging and snagging, year 1920-21......	291 921
Total channel maintenance, operating, and care expense for year 1920-21....................................	$1 353 894

The figures quoted represent only cash disbursements and include no allowance for interest or depreciation, except insofar as the depreciation has resulted in expenditures for renewals. Interest and depreciation should certainly be considered with the operating costs incurred by the Government and by the carrier in computing a financial summary of the operations of any waterway. Because the resulting balance sheet compares unfavorably with a similar statement for a railroad of like mileage, it does not necessarily follow that the waterway is a commercial failure. Its existence might be sufficiently beneficial to adjacent industries, development of territory, and increase of land values, to justify the enterprise, notwithstanding that it is supported in part by Government subsidies.

There is such variation in the length of service of the various parts of a movable dam that computing the proper allowance for depreciation to provide a sum for replacement would be difficult. Some of the wicket irons, for instance, have lasted only 5 or 6 years, whereas the concrete should last 100 years or more. Since a sinking fund of $1 per year, if invested at 4%, will produce $100 in about 40 years, it is believed that an allowance of 1% of the total investment in new work, added to the actual expenditures for repairs and replacements included in the annual disbursements, would be a sufficient allowance for depreciation. This is equivalent to the assumption that with yearly repairs and renewals at the present rate, the structures will last for 40 years and that the project should be charged with a sufficient sinking fund to produce the money needed for their replacement at the end of that period. The interest on the capital invested may fairly be assumed at 4% of the expenditures for new work.

With these assumptions, the total annual charges may be estimated roughly, as follows:

Total capital invested to date, about		$100,000 000
New capital needed to finish project		20 000 000
Total eventual cost of project		$120 000 000
Interest and replacement at 5% per year		$6 000 000
Operating expenses, 1921 (thirty-five dams)	$1 062 000	
Operating expenses after project has been completed (fifty dams)	$1 062 000 ÷ 0.7 =	1 500 000
Channel maintenance, dredging, etc		300 000
Total yearly maintenance, operating and care charges, interest, and depreciation		$7 800 000

These figures, although approximate, are probably more accurate than any estimate that can be made of the volume of traffic that will be moved through the agency of these expenditures. If the benefits are to be computed by comparing the present traffic with that prior to the construction of the improvements, then such benefits are nil, because the traffic now is less than before. It is known that such a pessimistic view of the value of the improvements is not justified, because, as will be shown later, events which have no relation whatever to the river and which could hardly have been foreseen when the project was adopted, have resulted in a large decrease in the river traffic; and without the present facilities the decrease in traffic would have been much more than it has actually been. The benefit to date, therefore, is not measured by the increase in total traffic since the improvements were installed, but by the increase in traffic over what it would have been without the improvements.

At the time the Ohio River improvements now in progress were planned, there existed a large down-stream movement of coal—more than 1 000 000 tons annually—from Pittsburgh, Pa., to Cairo, Ill., and several million tons from Pittsburgh to Louisville, Ky., and intermediate cities. At that time, there was no reason to suppose that this traffic would not continue and, in fact, increase considerably, if channel conditions were improved. This traffic from Pittsburgh to lower river points, however, has almost disappeared. During 1920, for instance, only nineteen coal barges passed Lock No. 13, near Wheeling, W. Va. The abrupt termination of the coal traffic from Pittsburgh was not due to the cost of moving the coal by water, which is, and always has been, less than by rail. Reliable information obtained by the writer, from cost records of a company engaged in transporting coal by water during 1921, indicates the cost to the carrier for a 250-mile haul to be not more than 5 mills per ton-mile, including the short haul by rail from the mine to the tipple, loading, towing loaded barges down stream and empties up stream, overhead, interest, and depreciation. Railroad rates for coal during 1920 were from 7.1 to 14.6 mills per ton-mile for a similar distance. Therefore, the disappearance of the commerce in Pittsburgh coal is not due to the ability of the railroads to haul it at less cost than by water. The general tendency for industries to use coal procured from local sources, thus avoiding the cost of long hauls, is to be

recognized in considering this decrease in traffic. A particular instance, having direct bearing on this traffic in Pittsburgh coal, is the greatly increased need for coal in the Pittsburgh District, following its large industrial growth in recent years, especially during the World War, resulting in the local use of a part, at least, of the surplus which in former years went down the river in barges. It is possible, also, that new markets, remote from the river, to which the coal is hauled by rail, have been developed in recent years.

It is difficult to estimate how much traffic has disappeared from the river from the causes named, but an examination of detailed records of tonnage prior to 1912, shows that the average commerce was 10 334 000 tons per year and that with the Pittsburgh coal traffic eliminated, there remained about 6 500 000 tons. The commerce for 1920 was 9 382 000 tons, an increase of nearly 50% in the traffic other than Pittsburgh coal, part of which increase was made possible by the expenditure for improvements. The statistics for 1920 show that there was a traffic of 417 129 000 ton-miles through the locks. If this traffic had been compelled to pay tolls equalling the yearly cost of maintenance, depreciation, and interest charges, about $5 600 000 in 1921, the tolls would have amounted to 13.4 mills per ton-mile. Adding this to the carrier's costs of, say, 5 mills per ton-mile, the total cost of moving the freight would have been about 18.4 mills per ton-mile, as against the prevailing railroad rates for a similar distance (126 miles), of from 12.5 to 13.9 mills per ton-mile.

Such a comparison, however, is not fair to the waterway. One should stop to consider that the project is incomplete; that the outlet by water to the markets beyond the Ohio River is no better than it was before the present project was commenced; that the railroads have built paralleling lines and are allowed to establish lower rates to meet water competition; that there is practically no co-operation between rail and water routes; that railroads charge more for hauling inland the freight from the river than that from other railroads; and that until these disadvantages are overcome, the capital for suitable floating plant, terminal, and transfer facilities cannot be found, and the water transportation companies must labor under the disadvantage of using improper equipment.

Railroads provide branches and sidings so as to connect the source of production with the warehouse of the jobber or consumer, but waterways cannot do this and thus cannot reach their full usefulness except by co-operation with the railroads. This co-operation should include mutual arrangements for shipping goods by rail and water combined, the acceptance by both rail and water carriers of goods for shipment over both routes on through bills of lading, equitable distribution of the through freight revenue between the rail and water carriers, and the provision of convenient terminal and transfer facilities and appliances for transshipment of the freight. There is little, if any, such co-operation on the Ohio River. In its place, there are artificial barriers which must be overcome before the river will amount to anything.

According to the report of the Chief of Engineers for 1921 (Part 2, page 22), railroad rates for similar distances are from 10 to 20% lower when there is water competition than elsewhere. The discrimination against river freight is shown also by the following example: The rate on coal in carloads from Charles-

ton, W. Va., to Indianapolis, Ind., is $2.80 per ton, *via* the Chesapeake and Ohio Railroad, to Cincinnati, Ohio, thence, *via* the "Big Four" to Indianapolis, of which amount the "Big Four" receives $0.91 per ton for its share of the haul, whereas coal brought from Charleston to Cincinnati by boat, then loaded in cars by the shipper, and turned over to the "Big Four", is charged $1.15 per ton for the same haul from Cincinnati to Indianapolis.

Thus, the railroads discriminate against river coal and cause the water carrier to overcome an artificial disadvantage, in this instance, of $0.24 per ton. The effect of such discrimination is to limit the market for river freight to the communities on the river banks.

As long as these artificial and discriminatory barriers exist, the gaining of profits by water carriers is so uncertain that the navigation interests will continue to suffer the disadvantages due to the use of antiquated and improper equipment, because of difficulty in raising capital, and the shippers, being compelled to pay the extra cost of this inefficient service, will be deprived of the benefits which otherwise would be obtained from the waterway.

The Ohio River is favorably situated for commerce. At its upper end, it terminates in the remarkable industrial area and region of mineral resources centering around Pittsburgh. At its lower end, it terminates in the Mississippi River which affords dependable, all-year navigation, either to the Gulf or to St. Louis, Mo., the former a distributing point for export business, the latter a gateway to the Middle West. Intermediate points along the Ohio River are such cities as Wheeling, producing coal, oil, and steel manufactures; Cincinnati, a manufacturing city and distributing point for other important manufacturing towns, and Louisville, a jobbing center for Kentucky, Tennessee, Alabama, and other States in the South. The Ohio River is fed below Pittsburgh by the Kanawha River, now shipping more than 1 000 000 tons of coal per year and capable of much larger production; the Muskingum River with its head of navigation at the important manufacturing city of Zanesville, Ohio; the Green River, penetrating to the center of the oil and coal-producing section of Kentucky, and the Cumberland and Tennessee Rivers communicating with Nashville and Chattanooga, Tenn. Reaching these important regions and cities, there can be little doubt that the Ohio River and its tributaries are situated so as to carry a large volume of traffic, if only the navigable depths are provided and artificial restrictions removed.

An instance of what can be done with water transportation on inland rivers, is seen in the operations of the Mississippi-Warrior Service. This service has arrangements with the railroads, whereby through shipments, part rail and part water, can be made on through bills of lading. It has modern boats and barges and is constructing efficient terminal and transfer facilities. After operating more than two years at a deficit, it began to earn profits on its Mississippi business, as the tonnage increased during the last three months of the fiscal year ending June 30th, 1921. In this period and the two months following, although the fleets operated at only part capacity and were served by unfinished terminals, the service earned a profit of about $98 000 after meeting all operating expenses and depreciation charges based on the high prices paid

for the equipment during and shortly after the war. The freight rates were from $5\frac{1}{2}$ to 40 cents per 100 lb. lower than all-rail rates for similar distances.

The Ohio River can be made navigable at less cost than the Mississippi; it is situated equally favorably for prospective business; and it, also, can be made into a profitable enterprise if a dependable channel is provided throughout its length and the existing discriminations are removed.

As the author states, an agency is required, the duty of which will be to manage the water-transportation problem other than the preparation of the waterway, but, in his statement that no such agency has been created, it is believed that he has overlooked the Inland and Coastwise Waterways Service, established by Act of Congress during the war, in order to supplement the greatly overloaded railroad systems. This agency is now functioning, and through one of its departments has built up the important Mississippi-Warrior Service mentioned previously. With proper support and sufficient appropriations, this agency should be in a position to foster the growth of the river-transportation business and promote the use of waterways for which many millions have been spent in channel improvements, but it can do little in promoting Ohio River commerce until the lower reaches have been made navigable so as to afford connection with the Mississippi River.

FREDERICK B. DUIS,* M. AM. SOC. C. E. (by letter).†—For some years, the writer has been connected with the construction and operation of Ohio River locks and dams in the U. S. Engineer District, Wheeling, W. Va., and, since 1915, Lock and Dam No. 18 to which the author's paper especially relates, has been included in the works under his charge. This discussion is based largely on information gained through experience in maintaining and operating these works.

Attention is invited to some apparent errors in the last paragraph of the historical data under the heading, "Introduction".‡ The locks and dams to Dam No. 39 are stated to have been constructed, but Dams Nos. 25, 27, 30, 32, 34, 36, 38, and 39, at the probable time of the preparation of the paper, were not completed, although Dams Nos. 25 and 39 were nearly so and will be ready for operation at the commencement of the low-water season of 1922. Dams, Nos. 41, 43, 44, 45, and 48 are stated to have been placed under construction, but Dams Nos. 41, 43, and 48 were completed and placed in operation in 1921, Dam No. 48, late in the year. At the end of 1921, there were thirty-four Ohio River locks and dams in operation.

Table 2§ gives the commerce carried on the Ohio River during 1894, 1916, and 1917. With the statement following this table, those figures indicate (although perhaps not so intended) a gradual decline of the commerce on the stream, in spite of the large expenditure for the construction of locks and dams. The facts are that the decrease in the commerce did not commence in 1894, nor has it continued to date. Reference to the reports of the Chief of Engineers, U. S. Army, will show that from 1894 to 1905 there was an average,

* Asst. Engr., U. S. Engr. Office, Wheeling, W. Va.

† Received by the Secretary, May 1st, 1922.

‡ *Proceedings*, Am. Soc. C. E., January, 1922, p. 3.

§ *Ibid*, p. 7.

although not a regular, increase, the commerce in 1905 amounting to more than 13 000 000 tons, of which about 3 700 000 tons were of coal from Pittsburgh to lower river points. From 1905, an average, but not a regular, decline in the traffic continued until 1917. By 1917, the coal traffic from the Pittsburgh territory to lower river points had practically ceased, the cause of which was in no way related to the river. The commerce previously cited for 1905 included that carried by ferries which, although not separately shown in the published report for that year, amounted to about 2 000 000 tons, as estimated from the amount of such traffic shown in later years when it was reported separately. The commerce given by the author for 1917 does not include the ferry traffic, so proper comparison with previous years when it was included requires that this class of traffic be omitted. Allowing for the 3 700 000 tons of coal carried in 1905, which traffic had ceased in 1917 for causes entirely foreign to the river, and also making allowance for the 2 000 000 tons estimated to have been carried by ferries in 1905 and not included in the author's figures for 1917, the actual decline in the commerce from 1905 to 1917, for which the cause may be attributed to the river, was approximately from 7 300 000 to 4 600 000 tons. Such were the conditions to 1917, but they did not so continue and, in the writer's opinion, the author has erred in not showing the commerce for the subsequent years as available from published reports, as the year 1917 was the turning point in the amount of commerce on the Ohio River and later data give a different aspect on the situation.

In the published reports available, the commerce for the three years since 1917 is given as follows: 1918, 6 171 412 tons; 1919, 5 400 377 tons; and 1920, 9 382 463 tons. This shows an increase of nearly 100% from 1917 to 1920. The decrease in 1919 compared with 1918 was due to the temporary depression in the industrial activities during the early part of that year. The large increase in 1920 was influenced in the opposite direction by the industrial situation but the amount of commerce carried in 1920 could not have been possible without the slack-water navigation then available. The question may be asked, why did the turning point in the amount of commerce occur about 1917, when the improvements had been under way for many years and a considerable number of the locks and dams had been in operation for some time? The answer is that not until about 1917 had the improvements progressed far enough to make them of practical benefit to navigation. In 1917, continuous slack-water navigation was made available from Pittsburgh to Dam No. 20, down stream 200 miles, and additional locks and dams providing intermittent pools were in operation from Dam No. 20 to Cincinnati. This practically insured a continuous navigable stage for craft of lighter draft, such as packet-boats, between Pittsburgh and Cincinnati. Craft requiring a greater depth of water than packet-boats could also operate over this section of the river with only infrequent suspensions on account of the river stages. It is, therefore, not a coincidence that, after 1917, the packet business which had almost disappeared from the upper part of the river, began to revive, as the result of the improvements. The foregoing data are in contradiction of the author's statement, in the paragraph on commerce, that he thinks the building of locks and dams is not rapidly increasing the tonnage and that under present methods

of operation no company carrying passengers and freight in less than barge loads has built up a trade and held it at a fair and profitable rate. The carrying of freight in less than barge loads has revived to a considerable extent and, to the best of the writer's knowledge, at a profitable rate. If it had not, the parties engaged in this business would not be gradually expanding their facilities, as they have been doing, even through the recent period of the most severe industrial depression that has been experienced in the upper Ohio Valley for many years.

A gradual increase in barge traffic, also, may be expected as industrial conditions improve, in fact, except for coal, it has been increasing in spite of the recent unfavorable conditions. One company, recently organized, has engaged in general towing in barge-load lots, considerable of its business consisting of the transferring of steel products from the Upper Ohio to Mississippi River points. The traffic manager of this concern recently informed the writer that inquiries for the services of the company were far more than its capacity to handle with its available plant, consisting of three towboats and a considerable number of barges. One steel company, in the Pittsburgh District, has also commenced transporting some of its products down the Ohio River with its own fleet.

The Ohio River Dam, selected by the author for description in his paper, was finished in 1910, and was the seventh to be completed, of the thirty-four that are now ready to operate. There are a number of items in its design and arrangements that have been found unsatisfactory and are now obsolete, and the later dams have a number of improvements devised since Dam No. 18 was built. It seems proper to refer to these changes and show the reasons for them, in order that the latest practice in the design of such structures will be on record.

A movable dam is one the purpose of which is to pass high waters without appreciable increase of stage over natural stages, to allow open-river navigation when the open river has sufficient depth, and to increase the depth to a navigable stage during periods of low flow. To answer these purposes the Ohio River dams have been provided with three principal elements: (1) the lock; (2) the navigable pass; and (3) the regulating weir.

Probably the most complicated of the operations on a movable dam are those connected with the regulation of the pools. The regulating weir is designed to pass water not needed for locking during periods of surplus, in such a way as to maintain a navigable depth in the pool above the dam. Its discharge capacity must be made variable by means of movable parts so as to correspond with the varying flow of the river. There are many conditions to meet, their relative importance is not seen the same by all designers and the appliances have not always worked in the manner the designers thought they would. For these reasons, there has been a continual change in the design and layout of the regulating weirs since the Ohio River improvements began and, even now, the opinions of the designing engineers have not crystallized into a definite standard arrangement for this important element of a movable dam.

The author's Fig. 8* shows a photographic view of the completed Dam No. 18. The navigable pass is of the same design as that which has been in use on the Ohio for many years, and no further mention of it is necessary, except with reference to the statement made by the author that the pine timber used in the construction of the wickets in this dam is the best wood for the purpose. As observed from service, oak is so much superior to pine in resistance to decay and physical injury that the latter wood is not being used at the present time for such purpose. To the best of the writer's knowledge the wickets at Dam No. 18 were the first on the Ohio River to be constructed of pine timber, and a few years later, pine was used at Dams Nos. 20 and 26, but at all the other dams constructed before and since, on this river, oak timber has been used for that purpose, and has demonstrated its superiority.

Considerable difficulty is being experienced in regulating the discharge through Dam No. 18, on account of the inadequate capacity of the two small bear-traps and unsatisfactory operation of the Chanoine wicket weir. The total discharge area of the two bear-traps is 1 350 sq. ft., whereas at all the dams, except one, in 150 miles of river up stream, the two bear-traps provide a total discharge area of 2 730 sq. ft., or more than double that at Dam No. 18. The result is that both the bear-traps at Dam No. 18 can pass less than one-half the quantity of water that can be passed by one of the two bear-traps in the dams above, the combined capacity of which is about sufficient for a 9-ft. stage in the open river, the maximum stage on which it is necessary to operate the dams. All additional weir area necessary at Dam No. 18 must be provided either by lowering the wickets in the Chanoine weir, for which it was designed, but is little used, or by lowering the wickets in the navigable pass, which was not originally intended, but which is now the usual practice. The amount of weir regulation necessary in this dam is further increased on account of its location between the mouths of two large tributary streams, the Muskingum River, 8 miles above, and the Little Kanawha River, about 4 miles below. These streams are subject to quick rises, with consequent sudden increases in the volumes of water poured into the pools above and below Dam No. 18, making quick action frequently necessary to provide for the sudden change in river conditions. The small discharge area of the bear-traps, therefore, makes frequent additional discharge area necessary for pool regulation. For this, the Chanoine wicket weir was designed, but it is an unsatisfactory and inefficient device. Like the weirs of this type used in nearly all Ohio River dams until a few years ago, it has been a failure and is little used. The unsatisfactory operating results of this weir are in part due to the elevation at which the wickets are hinged. At all other dams where such weirs have been used, the hinge points of the wickets are sufficiently above the center of resultant water pressure to prevent the wickets going on swing. At Dam No. 18, however, as described by the author, the hinge points were located so as to let the wickets swing automatically when the pools rise, in order to increase the discharge opening necessary in the dam. This feature has not been a success. The wickets will frequently swing when not necessary for pool regulation, to prevent which it is necessary to chain them to the service bridge. The idea

* *Proceedings*, Am. Soc. C. E., January, 1922, p. 33.

of automatic swinging of Chanoine wickets for pool regulation cannot be successfully applied on Ohio River dams. The rotation of wickets on their hinges is influenced by both the upper and lower pools, whereas, it should be dependent only on the stage in the upper pool. As there is no uniformity in the differences of elevation between the pools at varying stages, it is impossible to locate the hinge points on the wicket so that they will trip at a predetermined stage of upper pool.

Another factor making it impracticable to use this method of pool regulation is that when the wickets are on swing, the steel frames and bars, known, respectively, as the horses and props, by which the wickets are supported, hold so much drift above them that not only is the discharge capacity considerably reduced, but it is practically impossible to release the drift and right the wickets to close the opening, without lowering the whole dam to reduce the head, and, then, only with an expenditure of much time and labor. Therefore, when such wickets are operated, they must be completely lowered, but this is difficult and slow, particularly with the special winch provided. This winch, although designed for the purpose, is another feature contributing to the impractibility of operating the wicket weir. As stated by the author, too much time and labor are required. The winch is driven by a gasoline engine and is neither suitable in type nor has sufficient power. Even if a steam engine of sufficient power was used, the wickets could not be handled satisfactorily with it, on the heads necessary. The most difficult part of such an operation is the righting of the wickets after they have gone on swing, the nature of which operation is shown by the author's Fig. 10.* The difficulty of this operation cannot be appreciated by any one unfamiliar with it. Operation of the weir with the maneuver boat is a practical impossibility, because one bear-trap is between the weir and the lock side of the river, thus making it necessary to take the boat across the head of the open bear-trap, a difficult and dangerous operation.

These difficulties have resulted in the practical abandonment of the Chanoine weir as a regulating device at Dam No. 18 and other Ohio River dams. Regulation that cannot be done with the bear-trap, is now done with pass wickets, with the maneuver boat. This is possible for such heads as exist after the bear-traps have been opened and the difference in pool levels has been reduced. If the Chanoine weir was between the navigable pass and the first bear-trap, instead of between the two bear-traps, the service bridge could be abandoned and the shorter weir wickets operated with the maneuver boat. This method of pool regulation, however, is much slower and requires considerably more labor than regulating with bear-traps. The wickets also deteriorate rapidly under such hard service and make frequent repairs necessary. For these reasons, wicket weirs are not a satisfactory and efficient substitute for the successful bear-trap weirs developed and standardized on the Ohio River.

The preceding remarks concerning wickets relate entirely to the old Chanoine type. The author describes a new type, the Bebout wicket. Some of these wickets have been used within the last few years, for pool-regulating weirs, as a substitute for one of the two large bear-traps that previously were

* *Proceedings*, Am. Soc. C. E., January, 1922, p. 39.

included in the standard design of Ohio River dams. As described in the paper, these wickets will trip automatically, but they must be raised with a maneuver boat the same as Chanoine wickets. The author cites twenty-four advantages in the use of these wickets. Several years' experience with them has convinced the writer that not all of the claimed advantages can be realized in practice. On account of their automatic tripping feature, these wickets may be used with much benefit and success in some works, especially for weirs in dams where there is not sufficient back-water to effect their tripping, but neither these wickets, nor those of the older Chanoine type, can be used satisfactorily as a main regulating weir in Ohio River dams. The Bebout wickets might be used with benefit for a part of the navigable pass, as will be subsequently explained.

The Bebout wickets are hinged near the middle, like the Chanoine type, but unlike the latter, they lower themselves completely when the resultant pressure is above the hinge point, leaving an unobstructed opening in the dam, thus increasing the discharge capacity and avoiding the holding of drift as in the case of Chanoine wickets, which do not lower automatically but only go on swing. Leaving an unobstructed opening in the dam is of great advantage, but the automatic lowering feature of the Bebout wicket, just as the automatic swinging of the Chanoine wicket, although theoretically advantageous for regulating weirs in practice, is a detriment, because the automatic tripping cannot be controlled, as previously explained in connection with the swinging of the Chanoine weir-wickets at Dam No. 18, and in most cases occurs at other than the theoretical tripping stages.

All the Bebout wickets so far installed, except in one case, have been substituted for bear-traps, replacing one bear-trap of the two previously installed in each dam. In one dam both the bear-traps were replaced by the wickets. This has not resulted as favorably as anticipated by those responsible for the change and only recently has been abandoned and the two bear-traps have been re-adopted in the standard design for Ohio River dams. The wickets trip too frequently when not necessary for pool regulation or more of them trip than are required. They must be raised with the maneuver boat, the time for which cannot be chosen, but may occur any hour day or night. This requires considerable time and a crew of men that is not available from the regular lock-operating force, except during the day shift. When such maneuvers must be made during the remainder of the twenty-four hours, some of the employees on the regular day shift must be called. This is unsatisfactory and, furthermore, the maneuvers cannot always be made quickly enough to avoid objectionable irregularities in the pool stages. Also, the time consumed by the employees in such duties is usually at the expense of other important activities. In the Wheeling U. S. Engineer District, which includes the dam described by the author, there are dams with two bear-traps, dams with one bear-trap, and one dam without any bear-trap. The force of men employed is the same for the dams with one bear-trap as with two bear-traps, but the loss of morale and increasing complaints as to the amount of work at those dams which have only one trap, and the frequent calls for duty on the dam at all hours of the day and night, make it appear that, in a short

time, additional force will be required. At the dam where no bear-trap is used, and all regulating is done with wickets, it is now the practice to employ four extra men during the operating season of about nine months. Therefore, instead of the substitution of the Bebout wickets for a bear-trap requiring a less number of men for operating the locks and dams, as claimed by the author, the facts, as shown by experience, are that the labor is much increased and that it is not feasible to operate such a dam with a smaller force, but probably will require a larger force in the future. Also, the saving in cost effected by substituting wickets for bear-traps, cited by the author as another one of the advantages, is true only for the cost of construction. The cost of maintenance and operation is increased, the amount of which is not known, but probably is at least enough and perhaps more than necessary to compensate for the saving in first cost. The result, then, is no gain financially and a much less efficient and satisfactory method of pool regulation. It is the considerations just cited, which have convinced the writer that, in a long series of dams, the most satisfactory and the most economical appliance for regulating weirs is the bear-trap, as developed on the Ohio River. Enough of them should be used so that when more than their full capacity is required, except in rare cases, it will be time to throw down the dam and use the open river.

The Bebout wickets could be used with benefit for a part of the navigable pass at the end adjacent to the first bear-trap and hinged so high as to trip automatically only when the upper pool has risen to such a depth over the top of the wickets, that the whole dam should be put down. These conditions would usually occur only when the river has come to a stage where control of the dam has been lost and it cannot be lowered in the regular way by the maneuver boat. The automatic lowering of the wickets would then open a part of the dam and probably lower the upper pool sufficiently to make it possible to lower the remainder of the dam with the maneuver boat. The wickets installed in this way in a dam would afford a considerable protection against having the dam caught up on a stage of river when the lock is submerged and out of commission and navigation cannot pass over the dam. This accident has occurred a number of times, and any protection against it is worthy of consideration.

It seems proper in this discussion to refer to the problem of operating a long series of movable dams, such as that being built in the Ohio River. The problem is to raise the dams on a falling river as it approaches the minimum open-river navigable stage in such a way as to hold the water in the series of pools with a depth sufficient to maintain navigation. If the dams are raised too soon, no particular harm is done except that in case of an immediate increase in the natural flow instead of the expected decrease it may be necessary to lower the dam again and thus the labor of an unnecessary operation will have been incurred. If, however, the raising is delayed too long, the quantity of water in the river channel may be insufficient to fill the pools, and it may take several days for the natural flow of the river to supply the shortage. If one or more of the upper dams of the series have this trouble, they put on needles to close the interstices between wickets and, sometimes, even caulk the spaces with weeds, ashes, etc., so as to hasten the filling of their pools. This imme-

diately results in still further decrease of flow into the pools above the dams in the lower section of the series, aggravating their trouble. Until construction of the Lower Ohio River system of dams is completed, there are and will be stretches of open river through which considerable navigation is attempted. Owing to the great cost of dams and the expected troubles in construction and operation, it may be that the original intention to provide a series of dams all the way to the mouth of the Ohio River will be abandoned, and that navigation in the lower end of the river will be provided by open-channel regulation. In this case, an abrupt stoppage of the natural flow due to filling of the pools in the upper section of the river will cause sudden decreases in navigable depth in the lower part, which will be highly objectionable to navigation.

The ideal solution would be to raise all dams at or before the moment when the water contained in the channel is just sufficient to fill the pools. The operation of a movable dam at any given moment, however, is a practical impossibility. The maneuver boat must be moved to its place, each wicket must be raised separately, and accidents and delays occur. In general, it takes a whole day to raise a dam and unless the labor charge of operation is to be immediately doubled or trebled, it is impracticable to keep a crew available at all hours of the day and night. The river might be falling at the rate of about 1 ft. per day and at the close of the day's work the stage might be, say, 1 ft. above the ordinary raising stage, in which event the lockmaster would expect to raise the dam beginning the next morning. Late in the afternoon, however, several lockmasters farther up the river might have had to raise their dams because of the falling of the river to the closing stage. This produces a "cut" in the flow, and the lockmaster further down the river finds his stage falling so fast that he cannot get out on the dam and raise it in time to catch his pool. When he gets his dam up, he has to put on the needles and then the men farther down the river have even worse trouble.

With dependable communication by telephone and telegraph between dams, these troubles can be and are very often avoided, but the existing communication is not infallible. Some of the dams are on country telephone lines having from one to a dozen parties, because no other commercial service is available, and frequently all efforts to keep in touch with operations at the other dams fail. A private line down the Ohio River would cost more than $500 000 and entail an annual expense for upkeep, which would hardly be justified by the present commerce. Recent inquiries have been made as to the possibility of using a radio telephone system of communication, and it may be that some such system will be satisfactory. Reliable liaison between the dams is an essential feature of a series such as that on the Ohio River.

W. H. McAlpine,* M. Am. Soc. C. E. (by letter).†—The writer has read this paper with much interest, especially the conditions to be fulfilled in the design of the weir and the computations thereon.

The author's calculations "to determine whether the weir will regulate the upper pool when the water is at a 10-ft. stage" (Condition 1), by the formula, $Q = m\,(L'\,H')\,\sqrt{2\,g\,(h + Z)}$, could be made clearer by a statement

* U. S. Asst. Engr., Louisville, Ky.

† Received by the Secretary, May 3d, 1922.

of the relations of the zero of gauge to elevation of weir sill and pool level or crest of dam. It is not essential (Condition 1) that the weir have sufficient capacity to pass all the discharge at any special stages such as a 10-ft. stage, as part of the pass wickets can be thrown for that purpose. It is believed that the author has taken great liberty in assuming that values of m, derived from observations where the "swell head" was about 0.35 ft., are applicable to a case where the "swell head" is assumed as 1.7 ft. It seems questionable whether this formula should be used for cases of "swell head" as high as 1.7 ft. It is believed that a submerged weir formula is more applicable to the case. Using Francis' formula, with values of n deduced by Herschel, we have:

$$Q = 3.33b\,(n\,H)^{\frac{3}{2}}$$

$$b = 500;\ n = 0.63;\ H = 11.837$$

Solving, Q = discharge = 33 900 cu. ft. per sec., instead of 57 700 cu. ft. per sec., as found by the author. The formula, $Q = m\,(L\,H)\,\sqrt{2\,g\,(h + Z)}$, appears more applicable to Condition 2, and its use is better illustrated in the paper referred to by the author.* The lack of authentic experimental data as to the proper values of m makes the use of this formula unsatisfactory. It is believed that systematic observations should be made at movable dams to secure more reliable and complete data as to the proper values of the coefficient, m, under various conditions.

For investigating Condition 3, the author uses the formula of Chanoine and De Lagrene, namely,

$$Z = m\,v^2\left(\frac{S^2}{S^2_1} - 1\right)\frac{1}{2\,g}$$

in which,

Z = "swell head".
v = mean velocity (before construction of works).
S = discharge area of river before construction of works.
S_1 = discharge area of river after construction of works.
g = 32.2.

Z is assumed as 0.25 ft. and m as 1.05, instead of 1.5, when the "swell head" is reduced from 0.5 to 0.25 ft. After substituting the other known quantities, the value of S_1 = discharge area after construction of works, is found to be 18 250 sq. ft. It is not understood why the value of Z is assumed and the value of S_1 calculated, as the dimensions of the weir and the pass have already been determined, at least tentatively, to satisfy Conditions 1 and 2. It would appear preferable to substitute the tentatively found area, S_1, and calculate the value of Z to determine whether it falls within reasonable limits. No authority is indicated for using $m = 1.05$ instead of 1.5, the value of the coefficient used by Mr. Thomas in the paper referred to previously, for cases where the lock-gates are open. The writer has never found any justification for the use of 1.5 for the value of m in the formula, when applied to a lock in a large river, for a case when the lock-gates are open or for any other condition. The writer has compared the value of the "swell head", as de-

* *Transactions*, Am. Soc. C. E., Vol. XXXIX (1898), p. 471.

termined by this formula, in a number of cases on large rivers with the actual "swell head" and has found that the value of the coefficient, *m*, should be only slightly in excess of unity. Probably the value of 1.05 given by the author is about correct for the case in question. It is possible that in a narrow cross-section of river, the contractions due to lock walls, piers, etc., might be sufficient to justify a coefficient of 1.5, but certainly not in a wide river, with a dam composed largely of weir and pass sills.

Having found or assigned a value for Z, the author calculates the mean velocity for critical high stage, which is assumed to be at the top of the lock wall, by the formula:

$$V_1 = \sqrt{2\,g\,(Z + h)}$$

in which,

V_1 = mean velocity after construction of dam.

Z = "swell head".

h = velocity of approach prior to construction of dam.

The use of the two previous formulas appears to furnish a rather unsatisfactory and roundabout method of determining the velocity of the section. The values for "swell head" are rather meaningless to the average individual, unless converted into terms of velocity. Unless one is familiar with the subject, one has little idea whether a value of 0.5 or 1.0 is excessive. However, one knows at once whether a velocity of 5.7 or 8.0 ft. per sec. would be excessive. Also, the value found for "swell head" in the formula does not represent the entire head due to velocity of the current at the dam. To find the total velocity head, the calculated head due to velocity of approach prior to the construction of the dam must be added to the "swell head". In other words, if it is desired to compare the actual measured head due to velocity at the dam with the results from the formula for "swell head", the calculated head due to velocity of approach prior to the construction of the dam must be added to value found for "swell head". Although the two formulas, $Z = m\,v^2 \left(\frac{S^2}{S^2_1} - 1\right) \frac{1}{2\,g}$, and $V_1 = \sqrt{2\,g\,(Z + h)}$, may be used to determine either the mean velocity after construction of the works (V_1), with an assumed discharge area of dam (S_1), or *vice versa*, the general formula, $V_1 = \frac{Q}{S_1}$ may be used for the same purpose.

Let

V_1 = mean velocity at the dam after construction.

Q = discharge in cubic feet per second, as determined by the rating curve.

S_1 = discharge area in square feet of proposed dam.

S = discharge area before the construction of the dam.

Since, $V_1\,S_1 = V\,S$, $V_1 = \frac{V\,S}{S_1}$; but $Q = V\,S$, therefore, $V_1 = \frac{Q}{S_1}$.

If a coefficient other than unity must be applied to allow for sudden contractions, it may be applied to the general formula, $V_1 = \frac{Q}{S_1}$, as well as the

formula used by the author. Both the formulas, $Q = m\ (L\ H)\ \sqrt{2\ g\ (h + Z)}$, and $Z = m\ V^2 \left(\frac{S^2}{S^2_1} - 1\right) \frac{1}{2\ g}$, are modifications of the general formula, $Q = A\ V$, and their value depends on the completeness and reliability of the observations made to determine proper values of the coefficients to be applied under various conditions.

Some of the areas of the cross-section of the river bed given in Table 3,* for various stages, are apparently in error. For example, the difference in area between the 10-ft. and the 11-ft. stages is given as (20 540 — 18 350) 2 190 sq. ft.; and between the 11-ft. and the 12-ft. stages, there is a difference of only 1 270 sq. ft. Again, S is given as 24 600 sq. ft. for a 16.4-ft. stage, or an increment of only about 600 ft. for each additional foot, assuming the area of 21 810 sq. ft. for a 12-ft. stage to be correct.

The principal object of this discussion is to bring out the desirability of more complete observations as to actual velocities created by the construction of locks and dams and other obstructions, in order that reliable coefficients may be available for the formula selected for use.

* *Proceedings*, Am. Soc. C. E., January, 1922, p. 15.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

THE DESIGN OF AERATION UNITS AND SEDIMENTATION TANKS FOR THE ACTIVATED SLUDGE SEWAGE DISPOSAL PLANT AT MILWAUKEE, WISCONSIN

Discussion*

BY MESSRS. HARRISON P. EDDY AND ARTHUR L. SHAW.

HARRISON P. EDDY,† M. AM. SOC. C. E. (by letter).‡—This admirable paper is of particular value at this time, because it deals with a new and most interesting process of sewage treatment, and also because it describes features of a plant which, when completed, will be one of the largest in the United States for the treatment of sewage. As the paper deals essentially with the details and principles of design, it may be of interest to state briefly the reasons for adopting some of the features of the plant and for these particular designs.

At first thought, one might question the need of preparatory treatment of the sewage in grit-chambers, and, particularly, by fine screens. To understand the reasons for such treatment, it is necessary to have clearly in mind the process going on in the aeration tanks. In these tanks a large quantity of air is introduced under pressure, slightly in excess of the hydrostatic head of the overlying water, for the dual purpose of supplying sufficient oxygen to promote ærobic bacterial processes and of mechanically agitating the sewage. Sufficient agitation is required to cause the sludge floc to be swept back and forth, so that it may come into intimate contact with all the finely divided suspended solids and colloidal matter, in order that such materials may be absorbed by the floc and the clarification thus produced may be complete. It is equally important, however, that the agitation shall not be so vigorous as to break up the fragile floc and cause it to return to its former

* This discussion (of the paper by Darwin W. Townsend, Assoc. M. Am. Soc. C. E., published in January, 1922, *Proceedings*, but not presented at the meeting of the Society), is printed in *Proceedings*, in order that the views expressed may be brought before all members for further discussion. Subsequent discussion on this paper will be published only in *Transactions*.

† Cons. Engr. (Metcalf and Eddy), Boston, Mass.

‡ Received by the Secretary, April 26th, 1922.

colloidal state, and thus defeat the object of the treatment. Generally speaking, also, the more moderate the agitation, the less air and power required, and therefore the greater the economy.

Exhaustive experiments at Milwaukee, Wis., and elsewhere have demonstrated that the heavy and coarse solids tend to settle and remain on the bottom of the tank, notwithstanding the introduction of a substantial quantity of air, and that a greater quantity of air is required to hold such solids in suspension than would be necessary if they were removed and only the finer material was allowed to enter the tanks. Unless the coarse solids can be kept in suspension, they will remain in the tanks and form deposits on the plates. Even when the Milwaukee sewage was passed through a screen having openings of $\frac{1}{8}$ in. or less, in width, it was found that such deposits were formed when the volume of air used was reduced below about 1 cu. ft. per min., with a plate-tank ratio of 1 : 4.4. It was decided, therefore, that economy and efficiency of treatment required the use of grit-chambers and fine screens preparatory to aeration.

Whether there is an additional economy in fine screening on account of a reduction in the air requirements of the sewage when devoid of its coarser suspended solids, is a mooted question. That the removal of suspended solids, if carried to a sufficient degree, would render the sewage more easily treated, cannot be doubted, but whether fine screens can accomplish a measurable effect in this direction, does not appear to have been proven.

The comparative efficiency of treatment in tanks 10 and 15 ft. in depth, was made the subject of careful and prolonged study at the Milwaukee Testing Station. Tests carried out with the greatest care, under the personal direction of William R. Copeland, Affiliate, Am. Soc. C. E., Chief Chemist, showed that, taking all the facts into consideration, it appeared that, for the same quantity of free air per gallon of sewage treated, there was little difference in the work accomplished by the 10-ft. and the 15-ft. tanks. The 15-ft. tanks have produced an effluent of somewhat greater stability, whereas the 10-ft. tanks have accomplished a slightly greater reduction in suspended matter and bacteria. If one depth of tank has an advantage over the other in purification efficiency, it seems to be the 15-ft. depth.

An important consideration in the selection of depth of tank is the power required for compressing the air sufficiently to overcome the hydrostatic pressure of the several depths of sewage under consideration. In the cases of the 10 and 15-ft. depths, the latter would require 50% more power than the former, disregarding the effect of friction in pipe lines and porous plates. This saving will generally be offset, partly at least, by the increased cost of the larger area of tanks of the lesser depth. At Milwaukee, this is important, because of the cost of the bulkhead, the sheet steel enclosure, and the pile foundation. Another important factor there is the limited area available for the treatment plant, as it is felt that additional area could not be devoted to this purpose, on account of the requirements for harbor development.

Diffuser plates were early demonstrated to afford more satisfactory distribution and diffusion of air than any other method available, although it should be noted that there has been some conflicting evidence on this point.

Comparative tests of plate-tank ratios of, approximatively, 1 : 4.4 and 1 : 6, were conducted for a period of four months at Milwaukee. The tests indicate that there is a slight advantage in the larger proportion of diffuser-plate area. This slight advantage was the reason for the adoption of the larger ratio in the design of the plant.

The design adopted for the sedimentation tanks has given rise to more misgivings, on the part of engineers connected with the work, than any other feature described by the author. There is no precedent in this process for tanks of this size, and grave doubt exists in the minds of some as to the applicability of the experimental data to tanks differing so widely in size. There does not appear to be serious uncertainty as to the operation of the tanks as sedimentation units, although the larger the surface area, the greater will be the effect of the wind in causing the floc to remain in suspension and pass out in the effluent. The behaviour of the sludge accumulation, however, is a different matter. The success of the tanks, in fact, the efficacy of the entire process, depends in large measure on keeping the sludge as fresh as possible. It is important, therefore, to remove all the sludge promptly, otherwise it will tend to change in character, losing its "activity". If all the solids were to settle promptly to the floor of the tank, and the scrapers, or squeegees, could be relied on to push effectively the sludge to the center of the tank, the length of time in travel probably would not be long enough to permit material impairment of the sludge. This, however, does not seem to be the case. Most of the floc moves slowly in its vertical passage toward the bottom of the tank, and enters a horizontal trend of flow long before it reaches the bottom. In certain small-scale experiments, the writer found that the solid particles after settling to a substantial depth moved toward the center in an almost horizontal direction. If this tendency extends to so long a distance, that is, about 50 ft., the large tanks adopted should not present serious operating difficulties. However, if the sludge does not escape promptly and completely, it may be necessary to empty and wash out the tanks at comparatively short intervals. Although such procedure does not offer prohibitive difficulties, it would introduce an annoying feature of operation.

The depth of the settling tanks—15 ft.—was decided on for the purpose of affording sufficient opportunity for fluctuations in the depth of sludge accumulation or "blanket", which varies greatly from hour to hour during the day. This variation appears to be caused primarily by the changes in quantity and quality of sewage being treated, the quantity and density of return sludge being maintained as nearly constant as possible. Obviously, the smaller volume of weak sewage received at night does not yield as large a quantity of sludge as the greater volume of stronger day sewage. Hence, the sludge accumulation in the settling tanks—and to a less extent the sludge burden in the aeration tanks as well—varies greatly, even though the withdrawal of sludge is uniform as to volume and density. It is necessary, therefore, to provide ample storage capacity in the settling tanks to prevent the sludge from accumulating to a depth sufficient to force the fine surface sludge

blanket to pass out in the effluent. The fluctuations in depth of sludge of different densities during a typical day are shown by Table 3.

TABLE 3.

Density of sludge,* percentage.	Minimum depth, in feet, at 6 A. M. ±	Maximum depth, in feet, at 6 P. M. ±
1	6	12
10	3.5	9·5
90	2	5

* The volume of sludge remaining at the bottom of the test sample after standing quiescent in a glass cylinder, 2¼ in. in diameter and 16 in. high.

It is evident that there was some lag between changes in volume and character of sewage and those in depth of sludge accumulation, the minimum depth of sludge occurring at about 6 A. M. and the maximum at about 6 P. M., whereas the corresponding changes in the sewage occurred several hours earlier.

These measurements illustrate the normal fluctuations, although the depth can be controlled, within limits at least, by regulating the rate of drawing surplus or "waste" sludge, the sludge in excess of that required for treatment of incoming sewage.

Comparative tests were not made to determine whether there was particular merit in depth as contrasted with volume of sludge storage space in the settling tanks, although, theoretically, there would appear to be some advantage in a shallower tank of equal volume. In the absence of definite information on this subject, and in view of the rapid and large fluctuation in depth of sludge within the experimental tanks, it was decided to build the settling tanks 15 ft. in depth.

ARTHUR L. SHAW,* ASSOC. M. AM. SOC. C. E. (by letter).†—The writer has had occasion to study some features of the plans for the sewage purification plant, at Milwaukee, Wis., in connection with the work of Harrison P. Eddy, M. Am. Soc. C. E., as Consulting Engineer to the Commission, and has been much interested in the author's comprehensive outline of the net results, in structural terms, of the exhaustive studies on which the final designs of this notable purification plant have been based. (The word, "purification", is used advisedly, as it is believed to be more appropriate in the present instance than the word, "disposal". A process so scientific, and productive of such a high degree of purification, seems worthy of the former term, reserving the latter for use in the general sense, or for those methods which are less complete in treatment.) As a résumé of the basic data for the structural and hydraulic design of this plant, the author's paper will be of value and assistance to many designers who may encounter similar problems.

The designer of the Milwaukee works has been required to reconcile many conflicts between bio-chemical requirements and hydraulic and structural

* Designing Engr., Metcalf and Eddy, Boston, Mass.

† Received by the Secretary, April 28th, 1922.

limitations and, although the practical success of the measures adopted will not be proven until after the plant shall have been placed in operation, he deserves much credit for the patience and ingenuity which his plans reflect.

Almost without exception, precedent points to the use of the air-lift for raising the settled activated sludge for re-circulation. The decision to use centrifugal pumps in the Milwaukee Plant for this purpose, is, therefore, a courageous one; and the effect of these pumps on the operating efficiency of the plant will be observed with interest. If the sludge floc is measurably broken up in passage through the pump runner, it is not unlikely that an appreciable part of the time of detention in the aeration tanks, after the return sludge has been added to the incoming sewage, may be consumed in the restoration of floc, before the sweeping action of the activated sludge on the colloids of the sewage can become fully effective. It is probable, also, that the pressing of pumped sludge may present some added problems, especially when pressing is undertaken without re-aeration and consequent opportunity for re-flocculation. The prohibitive cost of raising large quantities of return sludge continuously by the relatively inefficient air-lift has influenced the selection of the more economical method of pumping; and the experiment would appear to be worth the trial, particularly as a return to the air-lift method could be effected with little difficulty, should it prove necessary.

In discussing the rate of returning sludge, the author has somewhat overemphasized his objection to proportioning the rate of returning to the rate of sewage flow when he states that:

"Owing to the 'lag' through the plant, due to the large capacity of the tanks, it is questionable whether the synchronous method of operation could be controlled so as to approximate even the conditions of operation which, at first thought, appear to be the most desirable."

As a matter of fact, barring the slight effect of storage due to the small change in head on the outlet weirs, any change in the rate of flow of liquor entering a tank would practically be instantly felt in a corresponding change in the rate of discharge from the outlet end. The prism of liquor in the tank would function as an incompressible piston, any change in the rate of motion at one end being immediately apparent at the other. The effect of large tanks and long periods of detention in causing "lag" or the smoothing out of sharp fluctuations in the rates of incoming flow is thus limited to that accomplished by the capacity for storage within the range between high and low-water levels in the tanks. This storage capacity, in the present instance, is only a small proportion of the total tank capacity, so that its effect is correspondingly insignificant.

A more important factor in the rejection of the synchronous method of returning, is the impracticability of meeting all the variables and uncertainties which enter into such a method. The character of sewage will change, as well as its rate of flow; the density of sludge is subject to wide variation at various seasons and even during any one day, and it is not only troublesome to determine the quantity of sludge of a given density necessary ideally to treat sewage of the character flowing at a given time, but there is no certainty that a sufficient quantity of such a sludge will be available at that time.

The decision to return sludge at a constant rate is thus based on sound principle and is borne out by the general success of this method at the demonstration plant, but it is to be noted that the channel and pump capacities provide for great flexibility in this respect. This is a wise provision, for it can be foreseen that conditions will arise, which may require radical departure from a fixed schedule of operation. For instance, when conditions are unfavorable, and a very light sludge is being produced, the sludge blanket in the sedimentation tanks will rise and may threaten to pass out over the effluent weirs unless the rate of sludge drawing is increased to prevent it. Uncertainties in this respect are enhanced by the adoption of sedimentation tanks of dimensions far beyond those of any experimental tanks.

The selection of Elevation + 3.00 as the maximum stage of the Lake for which to provide, recalls the results of an analysis of the records of the recording gauge maintained by the U. S. Lake Survey at Milwaukee since 1903, which indicates that the occurrence of lake levels at or above this elevation once in about thirteen years is not improbable. Like other large inland bodies of water, Lake Michigan is subject to tide-like fluctuations or "seiches", which, at times, show marked rise and fall with respect to mean conditions within a few hours. Should the maximum recorded surge or rise above the mean occur simultaneously with a recurrence of the maximum recorded monthly mean, a lake level of Elevation + 3.28 would result. Such an occurrence, however, would be of brief duration, and provision for Elevation + 3 000 seems adequate in the present case.

There is lack of supporting data for the selection of Kutter's $n = 0.020$ in aerated channels. Its adoption is purely a matter of judgment, and it is to be hoped that some agency will undertake to study experimentally the friction losses in the Milwaukee aerated channels when the plant shall have been placed in operation, so that, in the future, designers may have the benefit of data on this subject. Observations of the losses through the large sluice-gates of this project, operating as they do under low heads, would also supply information of which there is now a paucity.

A further field for research will be found in the air mains, which will offer opportunity for study of friction losses at relatively low pressures, particularly in bends, valves, meters, and other fittings, the present empirical allowances for which by various authorities are widely variant. Small losses, unanticipated, will be evident at the coal pile in a compressor plant of enormous capacity and in continuous operation, such as is required at a large activated sludge plant. Reliable data on these losses, therefore, will be of great value to designers of future similar plants.

This paper on the sewage treatment plant at Milwaukee contains many novel and interesting features of design. Those interested in the design and operation of plants of this type will look forward to the publication, not only of the analytical results of operation, but also of any hydraulic or structural data which operation may bring forth.

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PAPERS AND DISCUSSIONS

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SIPHON SPILLWAYS

Discussion*

By Fred A. Noetzli, Assoc. M. Am. Soc. C. E.

Fred A. Noetzli,† Assoc. M. Am. Soc. C. E. (by letter).‡—The author deserves much credit for having presented to the Profession such a comprehensive paper on siphon spillways. The various examples of existing structures of this kind, and the clear description of their action and efficiency, will undoubtedly prepare the way for a more general use of siphon spillways wherever the conditions are favorable.

The writer was particularly impressed by the various ingenious methods devised by the author for priming the siphon and sealing the lower leg against the entrance of air from below, without the use of a submerged outlet.

One of the main considerations entering the design of a siphon spillway is the determination of its efficiency. The author states that "properly designed siphons will have efficiencies of from 60 to 80%, but, for preliminary computations, the former figure should be used." The writer fails to find from the many examples cited by Mr. Stickney any definite information with regard to the best shape of siphon for which an efficiency of 75 to 80% might be effected. The tests cited gave efficiencies of about 60 to 65%, if one discards the figure derived for the spillway of Power Plant No. 2 at Rochester, N. Y., for which the data given are too uncertain to lead to a definite conclusion.

It would appear, therefore, that, at present, a factor of ignorance of from 20 to 30% (of 60%) is still involved in calculating the discharge of a siphon spillway. This seems to be rather high for a comparatively simple problem such as a siphon. There is no doubt that from a few systematic tests on siphons of different shapes, more definite conclusions might be drawn as to the shape of entrance and exit openings, radius of the bends, etc., to obtain for siphons the maximum efficiency possible under conditions such as occur in practice. It is hoped that laboratory tests will be made on models and the results compared with accurate and systematic measurements for existing siphon spillways, in order to enable future structures of this kind to be built more economically than is possible with the present assumptions of "60 to 80%" efficiency.

* Discussion on the paper by G. F. Stickney, M. Am. Soc. C. E., continued from April 1922, *Proceedings*.

† Chf. Engr., Beckman & Linden Eng. Corporation, San Francisco, Calif.

‡ Received by the Secretary, April 29th, 1922.

For siphons of the type illustrated by Fig. 5,* and used, for instance, for the Hetch Hetchy Dam, the water issues from the lower leg into the open air at a considerable velocity. It is often overlooked that in calculating the effective length of the lower leg of a siphon, the velocity head of the issuing water has to be deducted from the theoretical head of 33.9 ft. This fact is carefully considered by designers of draft tubes for turbines, and such tubes are enlarged somewhat toward the outlet end, in order to decrease the velocity of the water and the corresponding velocity head. It is impossible to realize the full theoretical amount of suction, and the practical suction head for draft tubes is generally limited to about 20 ft. of water column.

Assume, for example, a siphon having an effective head of $h = 25.0$ ft., and an efficiency of 60%, so that the velocity of the water in the siphon would be:

$$v = 0.60 \sqrt{2\,g\,h} = 0.60 \sqrt{2 \times 32.16 \times 25.0} = 24.0 \text{ ft. per sec.}$$

The corresponding velocity head at the outlet is,

$$\Delta h = \frac{v^2}{2\,g} = \frac{24.0^2}{2 \times 32.16} = 9.0 \text{ ft.}$$

Consequently,

$$h + \Delta h = 25.0 + 9.0 = 34.0 \text{ ft.}$$

This corresponds to practically the theoretical maximum atmospheric pressure at sea level, and, therefore, a suction head of 25 ft. appears to be about the limit for true siphonic action even under the most favorable circumstances.

In practice, a certain allowance has to be made for altitude and the daily and seasonal variations of the atmospheric pressure. It appears, therefore, that the safe limit of the length of the lower leg of a siphon which discharges freely into the open air is about 20 to 22 ft. For siphons with a submerged outlet the conditions are somewhat more favorable, and calculations will show, in every case, the limit for true siphonic action.

If the lower legs of such siphon spillways are made longer than the previous calculations would indicate to be safe, the water column is likely to "break" frequently, thus leading to intermittent flow and heavy shocks and vibrations which are known to accompany the abrupt changes of flow of water. The writer, therefore, is unable to agree with the provisions made, for instance, for the Alpine Dam and the Hetch Hetchy Dam for which the vertical distance between top of siphon and outlet is more than 30 ft. The length of the lower leg in excess of the limit for true siphonic action is not only without help as regards siphoning, but, in certain cases, it may be objectionable on account of the vibrations which result from occasional breaks of the water column. In addition, it involves unnecessary expense and is likely to lead to over-estimating the capacity of such spillways.

Although the formulas for calculating the discharge of siphons are simple, if the efficiency coefficient is known, the writer has found a graphical presentation of these equations helpful for quickly estimating the cross-section, length, and economical height of siphon spillways for any given amount of discharge, etc.

* *Proceedings*, Am. Soc. C. E., February, 1922, p. 180.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

CONSTRUCTION PROGRESS OF THE HETCH HETCHY WATER SUPPLY OF SAN FRANCISCO, CALIFORNIA

Discussion*

By Messrs. Joel D. Justin, Allen Hazen, and Fred A. Noetzli.

Joel D. Justin,† M. Am. Soc. C. E. (by letter).‡—Tunnels for inspection purposes and drainage, such as those described by Mr. O'Shaughnessy, have been used in high masonry dams for many years. They were used in the Vyrnwy Dam and, perhaps, in earlier dams. They have become standard practice; but drainage wells, lined with porous concrete blocks, such as those in the design of the Hetch Hetchy Dam, are quite recent.

The writer was connected with the construction of the Olive Bridge Dam of the Catskill Water Supply for New York City, in which, so far as he has been able to determine, the drainage well with porous concrete block lining was first used. These wells in the Olive Bridge Dam were about 12½ ft., center to center, throughout the entire length of the masonry section, and were located a short distance back from the up-stream face. The wells were formed by using porous pre-cast concrete blocks, with a hole cored through the block.

The theory of the action of these drains is that the water which forces its way through the interstices of the concrete of that part of the dam up stream from the drains, will be conducted through the porous block to the well in its center. Thus, most of the upward pressure which would otherwise exist on every horizontal plane through the dam, is assumed to be relieved.

The drainage wells are useful and, undoubtedly, accomplish a great deal; but, in the writer's opinion, the porous block is a delusion and a nuisance. At the Olive Bridge Dam, at first, these blocks were moulded of 1 : 4 : 14 concrete and the mixture was kept as dry as possible, in order to insure porosity. Even at an age of several months, so many of these blocks were broken that

* This discussion (of the paper by M. M. O'Shaughnessy, M. Am. Soc. C. E., published in February, 1922, *Proceedings*, but not presented at any meeting of the Society), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion. Subsequent discussions on this paper will be published only in *Transactions*.

† Chf. Engr., Depts. of Hydro-Elec. Power Plants, Water Supply, and Sewerage, The Ludlow Engrs., Inc., Winston-Salem, N. C.

‡ Received by the Secretary, April 19th, 1922.

it was necessary to increase the strength of the mixture so that they could be handled with some degree of safety by the derricks. The placing of the blocks was always troublesome, because they were so fragile. When they were firm enough to handle, it was generally because the concrete was more dense than it was supposed to be, and the blocks were not porous.

When the porous drainage blocks were set, it was endeavored to heap around them the dryest concrete available, but, in spite of all precautions, the mortar from the cyclopean masonry being placed on the dam would run into the pores of the block and clog them. Because of the convenience of the drains as catch-alls, it was impracticable to prevent the workmen from throwing into them sticks, laitance, and surplus grout. This effectively lined many of the drains with an impervious coating and, in some cases, they were entirely clogged and to open them, a length of 90-lb. rail suspended from a derrick was worked up and down like a drop-hammer pile-driver. It is the writer's belief that, in spite of the care exercised to secure porous blocks, there are few of them in the Olive Bridge Dam that are any more porous than the concrete surrounding them.

If this is so, why use porous blocks to form the drainage wells? When effectively porous, they have little strength; therefore, why not discard them and have drainage wells, say, 30 in. square, which is about the size of a porous block, located about 12 ft., center to center, along the dam? With the increase in the width of the wells, their effectiveness as vertical drains would be greatly improved. The drains could be built by using forms, and after the dam was finished the relatively impervious surface next to the form could be broken up by bush-hammering, as the size of the well would permit a small man to work in it with an air-hammer.

The writer is pleased to note that bulk cement is being used on the Hetch Hetchy Dam. In 1915-16, he was connected with the construction of the Wissota Hydro-Electric Project in Wisconsin, where bulk cement was used, and since then he has been convinced that for any job where a large quantity of concrete is to be placed from a single plant, there is a great saving in the use of bulk cement. In 1915, its use was a novelty, but the indications are that it will soon become standard practice for such work.

ALLEN HAZEN,* M. AM. SOC. C. E. (by letter).†—The Hetch Hetchy water supply for San Francisco is an important undertaking. The difficulties of the aqueduct line will be evident to water-works engineers from an inspection of Plate III,‡ which shows a 31-mile tunnel through the Diablo Range, and many miles of large-size high-pressure pipe line.

The writer in speaking before the Chamber of Commerce of Oakland, Calif., once stated that in order to secure cheap water in the San Francisco District from a mountain source comparable with that obtained by other Western cities, it would be necessary to arrange with the geologists to turn the Diablo Range (represented in Plate IV,§ in the Coast Range Division)

* Cons. Engr. (Hazen, Whipple and Fuller), New York City.

† Received by the Secretary, April 26th, 1922.

‡ *Proceedings*, Am. Soc. C. E., February, 1922, p. 151.

§ *Ibid*, p. 153.

through an angle of 90°, so that the line of the aqueduct would be parallel, instead of at right angles, to the mountains.

The difficulties of supplying San Francisco and the adjoining communities with water are perhaps greater than those involved in the supply of any other American city. Many of the larger cities have been built near abundant water supplies. Sometimes the water has been the reason for the location and growth of the city; but San Francisco was built on a harbor, which is one of the finest in the world, and its excellence is sufficient reason for the growth of the city. There are incidental disadvantages in this particular location, and one of them is that a water supply must be secured by overcoming unusual obstacles.

At present, the San Francisco District is supplied from sources much nearer the city than the Hetch Hetchy Reservoir, and these cheaper sources will, no doubt, continue to furnish the supply for many years. The ten years suggested by the author may pass, and several other like periods, before it is necessary to build the Hetch Hetchy Aqueduct. The climate of San Francisco does not lead to the large per capita use of water required in some other Western communities. The present per capita use is low, and the climate and the habits of the people are such that it is likely to remain low.

The local sources of water supply have considerable reserve capacity. With reasonable development, the supplies now owned by the Spring Valley Water Company, and held in reserve by that Company, will cover three times the present rate of output. This includes the Calaveras Reservoir, which alone will produce more than the entire present supply, and two other large prospective reservoirs on tributaries of Alameda Creek. Even the coast streams from the western slope of the peninsula south of San Francisco, although discarded in several engineering reports, are capable of furnishing a considerable quantity of water through the present Spring Valley System, at a unit cost that would be only a fraction of that of Hetch Hetchy water.

The reserves for the cities across the Bay, served by the East Bay Water Company, including Oakland and Berkeley, are not as great, but San Francisco is not building the Hetch Hetchy for them.

San Francisco may need the Hetch Hetchy badly at some future time. There is a wide belt of dry country beyond the present local sources and between them and the Sierras. If San Francisco did not now claim and hold a Sierra source, the time might come when she would be in need of water. Nothing can be said against the far-sighted policy of reserving an adequate supply of mountain water, but having said this, it is well to keep in mind also that when it is necessary to go for it, it will be very expensive water. It is for the best interests of the city that all the good cheap water near at hand should be developed before so much money is spent on a distant and costly source.

The author mentions briefly the proposed arrangement by which water from Calaveras is to be allowed to flow down through natural channels to Sunol, and through the present Spring Valley Aqueduct to Niles and then taken by pipes to a section of the Hetch Hetchy Aqueduct built in advance of the remainder, to carry the water to the present Crystal Springs Reservoir.

The writer understands that by this procedure all, or nearly all, of the 700 ft. of elevation at which Calaveras water is available, is to be lost. The water is to be taken practically to sea level and is then to be pumped into the Crystal Springs Reservoir at Elevation 283. Most of it will have to be pumped again before it reaches San Francisco.

It may be interesting to note in this connection that at San Francisco the mountains are near the sea, and elevations are high. The main distribution reservoir in the present system is at Elevation 365, and one-half of the total output is used at this elevation and above it. The cost of pumping from sea level to these great elevations is a matter of no small importance.

The best use of available resources would be to carry the Calaveras water through an aqueduct to be built on solid ground, south of San Francisco Bay, extending to a point on the hills back of Palo Alto, from which point a grade aqueduct could be built to the San Andreas Reservoir at Elevation 440, and thence by tunnels and pipes to the city at Elevation 365. Such an aqueduct would be a few miles longer than the route now proposed by the author, but, as it would avoid a difficult submarine crossing, there would be little, if any, additional first cost. By its use, Calaveras water, in a quantity more than the entire present supply, could be delivered at the Honda Reservoir level of 365 ft., without pumping. The water of the Crystal Springs Reservoir would flow by gravity to a lower distributing reservoir, and the only pumping needed to operate the entire system would be for ground-water from the Alameda County sources and for water required in high-service districts above Elevation 365.

The reason for the selection of the route now proposed, as stated by the author, is that it will "make available, without duplication of aqueducts, the additional Spring Valley water". This brief explanation hardly does justice to the situation. All the future growth in San Francisco that can be reasonably anticipated in financial arrangements now made, will not warrant a larger aqueduct than can be filled with Calaveras water. The business does not warrant a larger one, and neither the water company nor the city can afford to build now for greater capacity.

Calaveras water will fill such an aqueduct for all time. If such an aqueduct is used at any future time to carry Hetch Hetchy water, it can only be accomplished by wasting Calaveras water. There is no reason why Calaveras water should be wasted to make way for other water. The supposed saving by using a part of the Hetch Hetchy Aqueduct for Calaveras water, therefore, has no real basis.

The procedure of taking Calaveras water through part of the Hetch Hetchy Aqueduct with a sacrifice of its head will result in an increase in pumping costs and in investments in pumping stations, that will amount to great sums of money. Water may be supplied in this way; but water rates will have to be adjusted accordingly, and the consumers will pay for the economic waste.

FRED A. NOETZLI,* ASSOC. M. AM. SOC. C. E. (by letter).†—The history of the Hetch Hetchy Project is rich in incidents which interfered more or

* Chf. Engr., Beckman & Linden Eng. Corporation, San Francisco, Calif.

† Received by the Secretary, April 29th, 1922.

less with the progress of the work. Opposition for political reasons and hostility against municipal ownership of public utilities, united themselves for fighting this project, and, in addition, at certain times criticism was heard from various quarters with regard to purely engineering questions. Those times of uncertainties have passed, however, and the first unit of this great project is in full course of construction, uniting friends and former opponents in the common desire for a successful completion of the work.

The main single structure of this project is the Hetch Hetchy Dam, a structure of the curved gravity type, which will ultimately be more than 300 ft. high. For the initial dam, it is proposed to discharge the flood waters through a siphon spillway near the center of the crest, where the dam is highest. The writer would like to know the reasons for the adoption of a siphon spillway in preference to a spillway with radial gates, which was proposed as an alternative scheme when bids were asked for the construction of the dam. As the dam is to be raised later, all the siphons will be covered, and practically lost, whereas gates might have been salvaged and used again for the spillway of the raised dam.

It will be interesting to observe, during periods of floods, the effect of water discharging from the siphons and over the stepped-off down-stream face of the dam. The water will issue from the siphons at a velocity of about 25 to 30 ft. per sec. Assuming a maximum flood flow of 12 000 sec-ft., the total kinetic energy of this water, in dropping from the reservoir surface at Elevation 3 720 to the stream bed at Elevation 3 500, would be between 200 000 and 300 000 h. p., and that part of it which is expended on the dam no doubt will produce some vibrations.

This will afford an excellent opportunity for having such vibrations measured by recording instruments. At the same time, such tests may permit conclusions to be drawn as to the effect of siphoning over the crest of slender arch dams and the vibrations incidental thereto. It is believed that the large body of water back of the dam will reduce, if not practically nullify, such vibrations, because the combined mass of the dam and the water for a certain distance from the dam is so enormous as to make insignificant the stresses from vibrations caused by spilling. However, this assertion can probably be proved or disproved only by actual measurements, and it is to be hoped that such tests will be made on the Hetch Hetchy Dam in the interest of future structures to be built.

At the time when the Hetch Hetchy Dam is to be raised, the peculiar problem will be encountered of preventing any seepage water from accumulating in the planes of contact between the old and the new concrete, in order to prevent uplift for the added parts of the dam. In the writer's opinion, particular difficulties will be encountered in sealing tightly the smooth channels of the siphons, mainly on account of the natural shrinkage of the newly poured concrete which will tend to loosen it from the cover of the spillway channel and thus admit water to the stepped-off portions of the old down-stream face of the dam.

The Lake Eleanor multiple arch dam is an excellent representative of this type of structure. The dam is located at an elevation of 4 600 ft. in a region

of ice and snow. It would be of interest to know the effect of freezing and thawing, if any, on the slender arches of this dam, also the effect of ice pressure. It is to be hoped that the City of San Francisco will make funds available for measuring temperature, deflections, and stresses in the dams of the Hetch Hetchy water supply project, in order to furnish data which may be used to advantage when the time comes to raise these structures.

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PAPERS AND DISCUSSIONS

THE CONTINUOUS TRUSS BRIDGE OVER THE OHIO RIVER AT SCIOTOVILLE, OHIO OF THE CHESAPEAKE AND OHIO NORTHERN RAILWAY

Discussion*

By Messrs. C. A. P. Turner, T. Kennard Thomson, and Charles Evan Fowler.

C. A. P. Turner,† M. Am. Soc. C. E. (by letter).‡—This paper on the Sciotoville Bridge, coming as it does from an engineer who has earned his place in the front rank of the profession by the design and execution of one of the finest examples of long-span bridge construction—the Hell Gate Arch Bridge—will be received and read with unusual interest. The structure described is pleasing in appearance, satisfactory from the standpoint of rigidity and safety, and was erected in a creditable manner without mishap.

The span is somewhat in excess of those common in simple bridge truss design; but the fact that it is a double-track structure, and is wider and of correspondingly greater weight than a single-track railway bridge or the ordinary highway bridge, should extend the economic span length for the simple truss up to 850 ft. at least.

As an advocate of the continuous bridge, Mr. Lindenthal does not limit its application to long spans in place of the cantilever, but contends that it is economical for spans customarily regarded as solely within the province of the simple truss span. In assuming this position, he has raised fundamental questions regarding the underlying considerations affecting the economy of truss design.

The disadvantages of the continuous structure have been reasonably and fairly treated in the paper. They should not prevent the adoption of the type, providing economy results. However, if the economy claimed by the advocates

* This discussion (of the paper by Gustav Lindenthal, M. Am. Soc. C. E., published in March, 1922, *Proceedings*, but not presented at any meeting of the Society), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion. Subsequent discussions on this paper will be published only in *Transactions*.

† Cons. Engr., Minneapolis, Minn.

‡ Received by the Secretary, April 3d, 1922.

of the continuous truss is unsubstantiated by the application of mechanical laws governing economic proportions and form, then the field of the type is limited to long spans which, designed with economic depth for vertical loads as simple spans, would be top-heavy under the overturning moment of wind pressure.

In the now classic controversy between Mansfield Merriman, M. Am. Soc. C. E., and Charles Bender, on the relative merits of continuous *vs.* simple span bridge structures, Merriman as a strong point predicated the economy of the continuous truss as against the simple truss on the known economy of continuous beams of uniform section. Bender claimed that he could design a series of simple trusses which would meet the requirements of a given specification with less metal than his opponent could design a continuous bridge covering several spans.

It would seem that the analogy between the economical relations of the continuous beam to the simply supported beam is inapplicable to the relations of the simple *versus* the continuous truss frame, because the web is of constant section in the beam, whereas in the truss it is proportioned to meet the requirements only of the variation of shear along the length of the span.

Again, although the claimed ability of Bender to design simple trusses of less weight than the continuous frame proposed by Merriman, might decide the question of ability of the contestants, it would not necessarily settle or explain the principle at issue.

As in the case with the beam, the truss frame is called on to support the moment tending to elongate the bottom chord and shorten the top chord horizontally, and the shear or cross-breaking vertical force. The total weight of the frame is the sum of the weights of the members designed to support these different forces added to the weight of the floor system and lateral bracing.

Simple Bridges vs. Continuous Bridges—Parallel Chords.—With parallel chords, the cross-section and the weight of the chord decrease as the depth of the frame increases, and, conversely, the weight of the web increases as the depth increases. Therefore, in such a frame, the economic weight approaches a minimum when the weight of the web equals the weight of the chords, and this relation holds true whether the frame is continuous or simple.

Economic Depth Greater for Simple Span.—Continuity renders the live load shears resisted by the webbing somewhat greater than those in the simple span. Therefore, the web of the continuous span would be heavier than that for the simple span, but the maximum moments are smaller for the continuous span. If it is a through span with inclined end posts, the chord length is shorter in the simple span than in the continuous span and if, for this reason, the chords were assumed to be equal in weight with trusses of the same depth, then because of the difference in the webbing, the economic depth of the simple span would of necessity be greater. Parallel chord bridges, however, are not economical for even moderately long spans and, for these trusses of variable depth, there is a more radical difference in the relative economic depth than for the case of parallel chord bridges of the two respective types.

Economic Depth—Non-Parallel Chords.—Simple Spans.—The reverse law of summation of shears and moments is most favorable to the simple span. Thus, shear increases from mid-span to the support, and applied moment increases from the support to mid-span. Accordingly, the simple span truss may be made deep at the center and of small depth at the end. With the greater depth at the center where the shear is the least, the web members, although long, are light. With decreased depth toward the support, the heavy web members are short, so that by this arrangement the weight of the web becomes greatly reduced over the case of parallel chords. Moreover, because of the inclination of the chord, the inclined chord functions in a dual capacity, resisting both shear and moment, still further reducing the weight of the web which, with the parallel chords, was one-half the total truss weight.

Contrast this reverse law of summation, so helpful to the economy of the simple span, with the conditions which are unfavorable in the continuous span. The moment is greatest numerically over the support where the shear is greatest and to obtain depth to resist this moment, heavy web members become long in place of the correspondingly short members of the simple span resisting the same shear. The economic depth for the simple span thus becomes from 20 to 30% greater than for the continuous truss for more moderate spans with reduction, in view of overturning moment of wind for the longer spans.

As, with economic height, the web of the simple span would reduce to about one-third the weight of the continuous type, and the chord lengths would be less, the conclusion appears inevitable that instead of the economy claimed for the continuous frame, it is generally lacking in economy to the extent of 30 to 35%, as compared with the simple truss frame for moderate spans. The question of the economic frame or truss is only a part of the problem of economic bridge design. The lowest total cost is the object that the progressive engineer strives to attain, but rarely achieves. As he approaches it from a consideration of the minimum truss weight, other factors appear, which are antagonistic to the triangulation he has fixed on, for truss economy. It may be said that although the economic theory of design may appear to be very simple in theoretical works on bridges, in practice, it is otherwise.

The truss triangulation which gives apparently the least weight for the truss, commonly gives difficulty in obtaining desirable panel lengths for the floor system; the stringers are either too long or too short; there is always something that does not fit, and the resulting solution is a series of compromises to approximate the desired end. Again, in the longer span bridge, if the depth is economic for vertical loading, it will be ill proportioned to resist the overturning moment of severe storms, unless the floor is wide and the work heavy.

Viewing the Sciotoville Bridge as a continuous truss span, the writer believes Mr. Lindenthal has approached closely to the proper economic depth. His view that the steel weight is 20% less than that of a properly designed simple span is mistaken, and the writer would substantiate his view by the submission of Fig. 25, which shows the proportions of the Sciotoville Bridge, together with a suggested form of simple truss span which, approximate computation indicates, would be lighter than the continuous design by the

margin noted. The moment over the support and the moment at the center of the continuous and simple span design would be equal. As the simple span is about 10% deeper, the maximum cross-section of the chord will be nine-tenths as great in the simple span. As the simple span design is such that advantage is taken of the reverse summation of shear and moment to an extent impossible in the continuous span and, because of the greater inclination of the chord members in the latter, the web proper would be about one-third of the weight of the web of the continuous span and, again, the total weight of the chords would be less, because of the shorter length, and it would appear that as far as the truss frame is concerned there should be a difference of at least 35% in favor of the simple span as against the continuous frame.

Consider the floor system: As the panel length is shorter, the stringer moments will be approximately six-tenths as great for the simple span, and the dead load moment would be one-half as great. The floor-beams would be increased in number, but reduced in cross-section. The number of main joints in the truss would be few, with longer members to handle, thereby reducing details. Wide variation in the make-up of the top chord and end post of the continuous type would be avoided, and simplification of details would result from greater uniformity of sections. The breaking truss to stiffen the floor-beams laterally would be eliminated automatically and the lateral system reduced in weight by connecting the laterals at the center of alternate floor-beams. Lateral stiffness would be secured by full triangulated bracing on a smaller number of planes than the portal bracing used, with a corresponding reduction in weight. A batter of the trusses of 5 ft. from the vertical in the total height would add to the lateral rigidity and permit some reduction of section otherwise required for top lateral and chord bracing. The number of members which perform no work as truss members, other than supporting the dead weight of the chords, would be greatly reduced in the suggested simple span.

The simple truss design suggested might come somewhat outside the pale of precedent which Mr. Lindenthal commends in the work of the early builder, but because it is practical it should not be considered a criticism of the serviceable and excellent structure described in this interesting paper. Approach to the goal of ultimate economy, for which all engineers are working and may never expect to reach, must create precedent.

Erection.—The method of erection of the simple span in order not to exceed the cost of erection of the continuous bridge would likewise need to follow somewhat unprecedented lines. The fact that the river bottom is of sound rock would make the problem much simpler than dealing with the Missouri River where there is from 50 to 60 ft. of shifting silt. Leaving a wide channel under one span, as was done in the erection of the Sciotoville Bridge, would necessitate the cantilever erection of three main panels of one span, which would not appear to present any especial difficulty.

Although opinion may differ on the relative cost of erection of the two types, of the quantity of steel required for the same specified working stresses, any difference of opinion is readily solved by working out the designs and

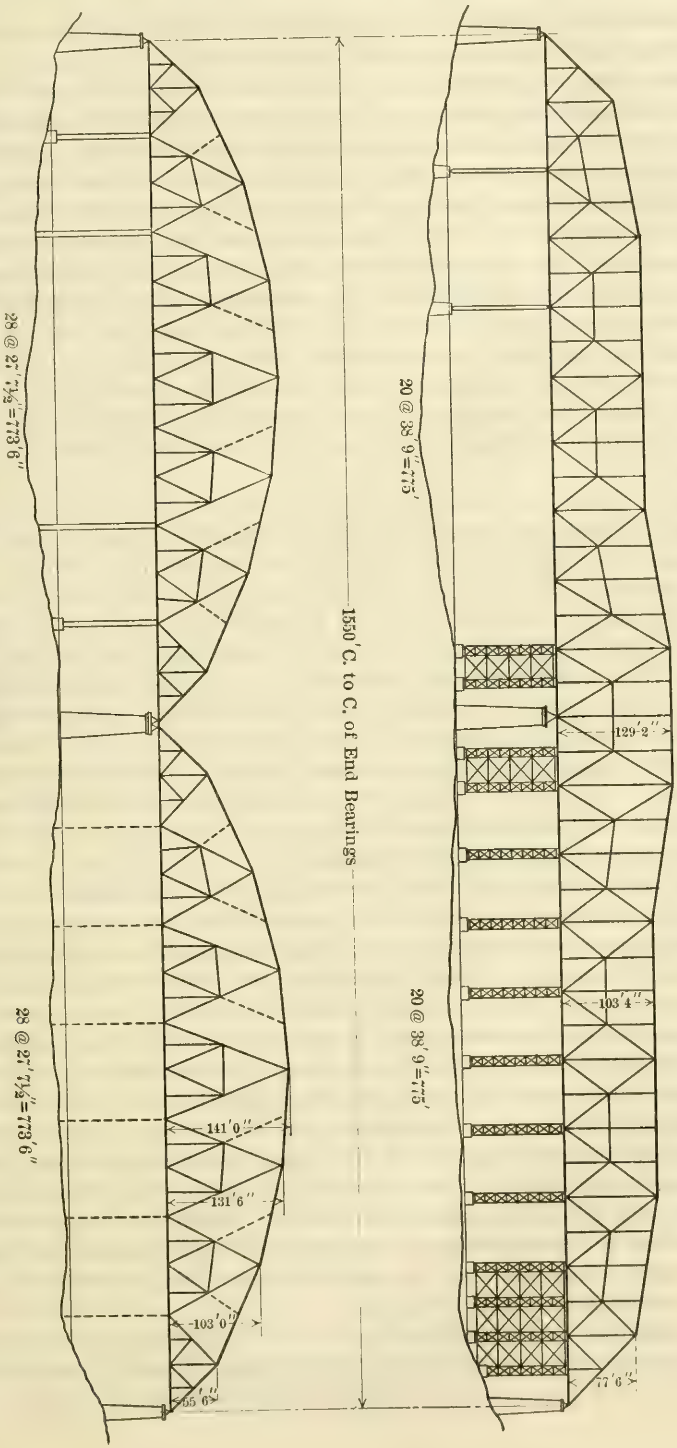
28 @ 27' 7½" = 773' 6"
20 @ 38' 9" = 775'
1550' C. to C. of End Bearings
129' 2"
103' 4"
141' 0"
131' 6"
103' 0"
55' 6"
77' 6"
28 @ 27' 7½" = 773' 6"
20 @ 38' 9" = 775'

Fig. 25.

calculating the weights, if the approximate solution by the application of mechanical principles is considered open to question.

Many American engineers have made as conscientious an effort as Mr. Lindenthal to design continuous truss bridges economically, impelled thereto by the mistaken assumption of some proportionate economy comparable to the divergence of the moment areas of the two respective types, only to realize, more or less, the heavy handicap imposed by the reverse law of summation of shear and moment favorable to the simple span and unfavorable to the continuous truss. In the comparison of the cantilever and continuous type, the moment areas approach identity for comparable depth and section over and between supports, and, therefore, it would appear that the discredit Mr. Lindenthal would cast on the cantilever truss should be focused rather on a degenerate section typified by all web and no flange, toward which the make-up of the compression members in many designs has carelessly approached and in the unfortunate instance of the cantilever the ultimate danger line had been passed.

In the foregoing discussion, the consideration of the web as that part of the truss between the external chords is a departure from the comparison of the equality of the web and chords in the parallel truss bridge. It would seem, therefore, that the inclined chord or end post might be apportioned as web or chord as the sign and cosine, respectively, of its angle of inclination. On this basis, a fair mathematical apportionment might be realized, an equalization from which reasonably satisfactory conclusions could be drawn as to the economic depth in the types under consideration. Because there is very little inclination in the chords of the continuous bridge, the apportionment suggested immediately indicates greater economy, as the hypothenuse of the triangle is less than the length of the other two sides, the sign and cosine of the angle of inclination, another viewpoint is had, from which comparisons and conclusions may logically be drawn.

The thory of economic truss proportions is too complicated to be embodied in simple mathematical form. The suggestion of Mr. Bender, that the best method of comparison of any two designs of similar types, without going into details too completely, was by multiplying the length of the members by the maximum stress thereon, and the sum total of the products should be a minimum for the economic frame, appears in the light of a good approximation, providing the uniformity of sections and such lack of wide variation as occur in the change of sign and intensity of the chord stress presented by the continuous truss, in comparison with the constant kind of stress and relative uniformity presented by the arched chord simple span. The wide variation in the stress of the chords of the Sciotoville Bridge undoubtedly accounts for the uneconomical thickness of the webs of the sections, their lack of breadth in proportion to the height of the truss, and that apparently unavoidable compromise in the make-up from which the designer would be free in treating the simple truss span.

If engineers are to consider the Sciotoville example as a riveted truss of unprecedented dimensions, they should not forget the old Forth Bridge with clear spans of 1 700 ft., and its riveted construction throughout. Riveted

construction in simple span design has the inherent advantage that rolled shapes which make up the members can be secured in very long lengths and so incorporated in the structure, reducing the number of joints necessitated by pin-connected chords, because of the facilities for fabrication and the necessity of making the joints at panel points for the proper connection of the laterals, which is immaterial when one is dealing with riveted sections.

The suggestion of a slight inclination of the truss might be objected to on the ground of difficult lateral connections, but this objection is more imaginary than real, as was demonstrated in the St. Croix River Arch.* Like Mr. Lindenthal, the writer appreciates the added advantage from the standpoint of stiffness which some indeterminate structures present, but this may be secured with the indeterminateness of the frame largely reduced for temperature and settlement, as was done in the structure noted. The adoption of the riveted sections throughout in the simple span permits partial erection as a cantilever, adapting the design to conditions under which the pin-connected frame is at a disadvantage.

It is generally assumed that the continuous bridge has some inherent advantages from the standpoint of stiffness, as compared with the simple span. If, however, the economic forms, and maximum deflections are compared, this will not be found to be true, as maximum deflection with the continuous bridge occurs when some of the spans are loaded and others unloaded, and with its smaller depth at mid-span and with partial restraint only at the support and its smaller chord section, the maximum deflection will be found to be greater than with the economically designed simple span. The difference, although in favor of the simple span, is insufficient to offset material economy did that, in fact, pertain to the continuous bridge.

Diverse Laws of Economic Chord Inclination in Simple and Continuous Spans.—As the apportionment of the efficiency of inclination of the inclined chord in the simple span is as the cosine of its angle of inclination in resisting horizontal deformation of moment, and the sine of its angle of inclination in resisting the vertical deformation of shear, its efficiency in resisting shear and moment is as the secant of its angle of inclination is to unity, compared with horizontal chords on a unit weight basis.

Because of the reverse sign of the bending moment in the cantilever parts of the continuous span, there is a reversal in this law of economic efficiency. Take, for example, the member of $U\,18$ to $U\,14$, in the author's continuous bridge design. For negative moment, its efficiency in resisting horizontal moment deformation is as the cosine of its angle of inclination. Its efficiency in resisting vertical shear is likewise as the sine of its inclination, but it carries that shear vertically a longer distance upward from the point of reaction, $L\,20$, thereby increasing the material necessary to support it, instead of decreasing the material necessary to support the shear, as is the case with the inclined chord where the moment is positive. Accordingly, the cross-section of $U\,18$–$U\,14$ presents a total efficiency in resisting combined shear and moment of an amount equal to the cosine of the angle of inclination instead of the

* *Transactions*, Am. Soc. C. E., Vol. LXXV (1912), p. 1.

secant of the angle of inclination, as is the case with the inclined chord of the arched simple truss span.

It is true that this inclination reduces the section required in the member, U 18–U 18, so that the economies of inclination are the algebraic sum of the plus and minus savings instead of the consecutive positive summation, as with inclined chords in the simple truss span.

The Latitude of Compromise of the Divergent Economic Requirements of Floor and Truss Panels Unfavorable to the Continuous Span.—In the foregoing discussion it has been noted that truss triangulation frequently conflicts with economic floor paneling. Thus, comparing from the standpoint of the simple span suggested, the bending moment of the four lines of stringers is 70% greater in Mr. Lindenthal's continuous truss than in the simple truss diagram suggested by the writer. The dead load bending moment is about 100% greater; whereas, conversely, beam shear and bending moment of all the beams is approximately 10% greater for the simple span than for the continuous span partly offset by the greater dimensions laterally of the chords which would naturally be used. Accordingly, the range for compromise adjustment is the difference between one clear dimension for the simple span against two shorter dimensions, that is, the cantilever arm and the suspended span in the continuous truss of two spans, or three, if the span is an intermediate span, with an economic location for the point of inflection inharmonious with favorable panels for either cantilever, suspended span, or floor.

This is a practical disadvantage of no small importance, which should not be overlooked in a theoretical survey of the two types of construction. General experience with continuous draw-spans gives the practical engineer a better basis for a comparison of the stiffness of two-span continuous structures with single span structures of the dimension of the length of the arm, than the relations of bending and moment forces presented in works on bridge design, and from this experience conclusions regarding stiffness are diametrically opposed to those customarily drawn from incomplete theory of resistance based on moment and neglecting shear.

Among engineers, experienced in the art of bridge construction, few are egotistical enough to assume ability to design the most economical frame possible to devise, yet it would seem that a thorough discussion of theoretical principles should lead to less divergence of opinion. With theoretical treatises on continuous bridge construction estimating from moment distribution an economy of 25 to 40% in the material required for the continuous truss bridge, and practical experience and conscientious design apparently indicating a lack of economy of 35% for a two-span continuous structure to 25% for a four-span continuous structure, from consideration of essential provision for combined shear and moment and the relations indicated by the constant of the moment magnitude equations, as well as numerical values of the three-moment equations, there appears indeed ample room for harmonization of book theory and practical experience as it is viewed by those who take the negative side of the economic question and ample room for explanation on the part of those who assume the affirmative side. Undoubtedly, the author's closing discussion in the affirmative will be interesting and instructive.

In closing this discussion, the writer thanks Mr. Lindenthal for the presentation of a most interesting and valuable paper, which skillfully treats of many practical questions and discloses meritorious details in advance of current practice. Preference for the continuous bridge of moderate span differs from the majority opinion of American bridge engineers, because of lack of demonstrated economy on a scientific mathematical or design basis.

T. Kennard Thomson,* M. Am. Soc. C. E.—Reference has been made to the danger of placing false-work in the Ohio River, which reference is fully appreciated by the speaker, as he was Engineer of Bridges for the Ohio River Division of the Norfolk and Western Railroad when, in 1890-91, the Kenova Bridge was built a few miles above the site of the Sciotoville Bridge. At Kenova, the records showed a low-water depth of 6 ft. and a high-water depth of 106 ft.

The author has called attention to the desirability of rock foundations for continuous girders. Any departure from this fundamental should only be adopted after the most careful consideration. For example, a sufficient number of piles might be driven to carry safely several times the designed load; but unexpected contingencies may divert a river in such a manner that these foundations would be seriously imperiled by undermining. Again, the teredo, which had never been known in the locality before, might obtain access to the piles.

Some years ago, it would have been considered safe to cut piles off 30 or 40 ft. under water, as the teredo was only supposed to find access to the piles between high and low water. About twelve years ago, however, the speaker was retained to report on a highway bridge at Fall River, Mass., where one end of a pier had dropped 2 ft. in one night. A pile head was cut off and brought up with live teredo and also limnoria, both actively boring.

The piles had been cut off 30 or 35 ft. below the surface of the water and 4 ft. of timber grillage, carrying masonry pier, had been sunk on top of these piles. The bridge had been completed just two years prior to the collapse of the pier. As the piles were cut off at such great depth, and as there was a sewer discharging within 150 ft. of the pier, it would have been considered safe against the ravages of the teredo.

The speaker, however, has never been able to satisfy himself as to whether the teredo and the limnoria obtained access to the piles after they were driven, or while they were floating on the surface of the water before being driven. In any event, great care should be exercised against allowing piles to float in teredo-infested water before driving.

As the Fall River Bridge did not have continuous trusses, no serious damage was done. A coffer-dam was built around the pier and concrete was forced under the grillage around the old pile-caps and brought up outside the pier, above the timber grillage line, to form a new support for the bridge and to prevent any further damage by the teredo. The steelwork was then jacked back to its original position on a new bridge seat.

Charles Evan Fowler,† M. Am. Soc. C. E. (by letter).‡—The present era of bridge building may well be termed the long-span bridge era, as it is now

* Cons. Engr., New York City.

† Cons. Engr., New York City.

‡ Received by the Secretary, April 27th, 1922.

possible to span wide rivers, estuaries, or canyons more scientifically and economically than at any past, or, perhaps, any relatively near future, period. The Sciotoville Bridge is a striking example as to what may be accomplished by the use of continuous bridges. It is the longest of that type ever constructed and now gives to America the proud distinction of having the longest spans for every type of bridge construction, namely, the Sciotoville Continuous Bridge, the Hell Gate Arch, the Quebec Cantilever, the Williamsburg Suspension, the Metropolis Simple Truss Span, and the Willamette River Draw-Bridge.

The piers of the Sciotoville Bridge are illustrative as to what should be done in the reinforcing of monolithic concrete piers, not only for the prevention of cracks, but as providing a strong protective shell for resisting the impact from ice, logs, scows, or collisions from steamboats. For this purpose, the writer's practice has been to use wire cloth, placed 3 or 4 in. inside the surface of the pier, and it is economical and effective. The care exercised in obtaining a proper foundation for these piers is to be commended, as it is a fundamental and vital matter in the building of long-span bridges.

The appearance of the bridge is peculiarly pleasing when one considers that it is a two-span structure, with outlines formed by straight lines. This satisfying feature is due to proper depths of trusses and a strictly symmetrical structure. The system of trussing adopted is, also, without question the best that could have been selected and one well adapted to meet the problems that arose in the method of erection. These results were evidently achieved as a result of a trained judgment and careful investigation. It is no surprise, therefore, to know the final outcome as to the economy and efficiency of the structure.

The unit stresses used in making the design should receive careful study by the Special Committee on Specifications for Bridge Design and Construction, and all engineers having to do with the design of steel bridges of any magnitude, as engineers can no longer be so wasteful of the resources of Nature as they have been in the past. The loading adopted undoubtedly will prove heavy enough for the future, as the uniform train load was the governing one for the main truss members, and with the margin allowed inside the elastic limit of the material, the floor and primary truss members will probably never be wanting in strength. The use of riveted construction throughout is to be commended, as the structure in consequence thereof is much stiffer and more lasting, thus nullifying the slight decrease in cost that the use of eye-bars would have effected.

The salient points of this structure, as well as of this type of bridge, have been so well covered in the paper that the writer will not comment on them, but engineers should study them carefully and endeavor to absorb those larger problems of design which have been solved so well.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

CORE STUDIES IN THE HYDRAULIC-FILL DAMS OF THE MIAMI CONSERVANCY DISTRICT

Discussion*

By Messrs. George L. Dillman, Allen Hazen, H. F. Dunham, and Thomas H. Wiggin.

George L. Dillman,† Esq. (by letter).‡—Tightness and safety are two entirely separate problems in dams, in this case, earth dams. Tightness can be, and often is, obtained at the expense of safety. This is the case when the most nearly water-tight surface is too far down stream. Safety can exist in leaky dams.

The attempt to solve the two problems by one idea has resulted in cores of sluiced material, puddled clay, masonry, concrete, and steel. All central cores are a mistake, not always failures, but always uneconomical.

If sluicing is a cheap method of moving material, it is advisable. It was used largely in the construction of the San Leandro Dam, for many years the highest earth dam in the world. Sluicing was well known to Chabot, and had been developed by hydraulic miners in California. Dikes were not made to confine the sluiced material, but to train it. The fineness or coarseness was not measured, nor thought of. The sluiced material was mixed with scraped and dumped material, filling most of the interstices therein.

A great deal of the Gatun Dam was sluiced, the original intention being to haul the material of the Culebra Cut by trains, but it was found to be cheaper to waste the cut and borrow for the dam. The core at the site was cheap, irregular, and enormous, and its economic width was not discussed, probably not thought of.

Slides have occurred during the construction of many of these soft cored dams (sluiced material or puddled clay). Such troubles come from weak dikes or overtopping. The cores are viscous, and the dikes must act as dams

* This discussion (of the paper by Charles H. Paul, M. Am. Soc. C. E., published in March, 1922, *Proceedings*, but not presented at any meeting of the Society), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion. Subsequent discussions on this paper will be published only in *Transactions*.

† Engr., San Francisco, Calif.

‡ Received by the Secretary, April 18th, 1922.

to hold them. Two dams are built in order that one may result. If construction can continue to completion, safety is certain as far as cores are concerned. Contact and wasteways are other questions.

The fineness or coarseness of material is inconsequent, provided there are enough fines to enclose the coarse. Cyclopean concrete is not more pervious than other masonry, when it is properly placed; this is also true of core material. Water drains faster from coarse material; therefore, this question only concerns the rate of progress. Drainage may be facilitated by tiling.

Although an insignificant percentage of coarse sand and gravel went into these cores, it does not follow that 10, 15, or even 20% of gravel would be detrimental; because 78% of fine silt and clay was the average content, it does not follow that 100% would have been bad. There seems to have been no reason for wasting some material and borrowing other, except to obtain a pre-determined mixture, for which the reason is not apparent or real.

The reason for thickness is only to insure continuity. A foot in thickness is as valuable for tightness as that used. Tightness is not essential to safety, but drainage is essential. When the most nearly water-tight surface is at or near the up-stream face, any reasonable section will make a safe dam. On streams like the Miami, it would be impracticable to keep them leaking for many seasons. The Mackay Dam on Big Lost River in Idaho is cited, the foundation of which and the adjacent material for construction was limestone gravel. Any scheme for making the dam tight would have made the cost prohibitive. There was no clay, little silt, hardly any sand and cement was out of the question, therefore, the verdict was "let her leak"; and it did leak, through, under, and around the dam. The leakage was 160 cu. ft. per sec. the first time the reservoir was filled, but the dam was always safe; the leakage was no more than had to be passed for prior rights, so no loss occurred.

The only care in construction was to have the up-stream face the most nearly water-tight surface. The bulk of the material was excavated by steam shovel and moved to place in cars. A small part was segregated, the fines being placed on the up-stream face and the coarse, on the front or downstream face. Some rock was quarried to increase the rip-rap, and a bar of material somewhat finer than the average, was borrowed to increase the fines of the up-stream face.

Of the thousands of springs developed, not one shows roil; there was never any piping; there was no danger. Continued measurements show that the dam is tightening. The reservoir was first filled in 1918, and has been filled annually since.

The Miami dams are not criticized as being unsafe, but as being uneconomical. Absolute tightness was unnecessary, and the attempt to get it cost much money. If there is leakage past the cores, they will never become tight. The up-stream face will gradually become the most nearly water-tight surface and safety will be increased thereby. An inexpensive segregation of sand and gravel (the material of the body of the dam) is all that was necessary to insure safety. After that, tightness could not have been prevented.

Nothing is said by the author about performance, although two of the dams were completed before the paper was written. Another point of importance, wasteways, is not discussed. It is to be hoped the author will allude to them in his closing discussion.

ALLEN HAZEN,* M. AM. SOC. C. E. (by letter).†—This paper is a statement of what can be done with material of hard-grained particles from the terminal moraine of the glacial period of Ohio. It will be well to remember that other physical properties may be found in other stock and in other parts of the United States.

The author speaks of the decided advantage in having a surplus of core material in the stock so that a part, at least, of the finest of that material may be wasted. This means practically that the effective size of that which remains and forms the core will be increased. Mechanical analyses of representative samples of core material are given, but the effective size has not been computed, and there is difficulty in doing so, because the finest size of separation is greater than it, and results can only be reached by extrapolation. The writer has plotted these results on logarithmic probability paper and, by extending the line downward, he finds that the effective size of the average of the samples is 0.0025 mm. The author does not state whether the mean or greatest diameter was used, in describing the size of the particles. Assuming that the mean is intended, this material is coarser than the material from cores of some other dams that the writer has examined, and shows the beneficial effect of wasting some of the finest particles. In addition to the greater grain size, there are differences in physical properties between the hard-grained particles of glacial drift and the much softer particles resulting from the disintegration of soft rock in other places.

The voids in the core material are not stated by the author, but he does give data from which their amount may be inferred.‡ Proceeding in this manner, it appears that the Lockington core had from 42 to 44% and the Englewood core 46% of voids. The weight per cubic foot of wet core material stated to be 121 lb., indicates 43% of voids. These results are consistent and indicate a slightly greater degree of consolidation than was found at the Calaveras Dam in California at the time of the slip.

The use of, and the results obtained by, the Goldbeck pressure cells are interesting. The writer doubts whether useful deductions can be safely made from these results at this time. In the first place, an idea of the degree of accuracy of the gauges may be obtained from the charts for vertical pressure. The vertical pressure certainly exists to the extent of the full weight of the material, and if the gauges were correct the indications would correspond to that weight. The figures taken from the diagrams do not appear to do this.

The observations at Germantown on March 20th, 1920, showed a pressure of 20 lb. at a depth of 26 ft., indicating 92% of the computed weight of the material at 121 lb. per cu. ft. At a depth of 53 ft., a pressure of 30 lb. was indicated, or only 68% of the computed weight. At Taylorsville, on Novem-

* Cons. Engr., (Hazen, Whipple and Fuller), New York City.

† Received by the Secretary, April 18th, 1922.

‡ *Transactions*, Am. Soc. C. E., Vol. LXXXIII (1919–20), Table 5, p. 1792.

ber 26th, 1921, a gauge at a depth of 67 ft. showed 50 lb., or 89% of the computed weight of the fill above it. The indications are that all the gauges under-register and that variations occur between the several gauges, that are not accounted for. For horizontal pressures, the gauges indicated somewhat less than vertical pressures at the same points for the greatest depths.

When core material is soft, the horizontal and vertical pressures are equal. As the work of construction proceeds, and more material is placed above, and as the core becomes consolidated, the horizontal and vertical pressures presumably remain more or less equal, unless something happens to disturb the equilibrium. A movement or flow of core material would be caused either by an increase or decrease in horizontal pressure. To cause movement the change in pressure would have to be sufficient to overcome whatever degree of stability had been reached to that time. Between these limits, far apart, is a broad range of pressures through which the material is always stable. Tests that showed the actual horizontal pressure at the moment when movement or flow began, would certainly be interesting. The pressure that exists with no movement would seem to have no significance; it might be anything within the limits of stability and probably would not differ widely from the vertical pressure.

The description of experience with actual breaks in the sides of dams, during which the core material was eroded and exposed, is one of the most valuable parts of the paper. It shows that the core material had attained a considerable degree of stability at the times of the breaks, but it must always be remembered that stability of such material is dependent, in considerable measure, on the height of the exposed face. Soft material is stable as long as the height is not great. Every material has its limit of height, and the greater the cohesion the higher the limit. At the Calaveras Dam, it was found that a material that would stand at one height, would flow almost as a liquid at a greater height.

The hydraulic method of dam construction is a most valuable one and the author has made an important contribution to the useful knowledge of it.

H. F. Dunham,* M. Am. Soc. C. E. (by letter).†—There are few words subject to more interpretations than "soil", and "silt". Weight as well as fineness are distinguishing qualities. An analysis for size and a determination of specific gravity of the material when dry and when saturated would convey quite a definite idea of the core material and could be used for comparison in other parts of the world. Is a combined size and weight table available? The author has "broken ground" in core-wall investigations and should have credit for incurring the expense necessary to determine the changes that a hydraulic fill undergoes. The writer would make a suggestion in regard to a pressure cell.

On the center line of the core, erect a cylinder or hollow mast, 28 or 30 in. in diameter, of thin metal, say, $\frac{3}{16}$ in. in thickness, or thick enough to withstand the exterior pressure, made up of sections suitable for riveting and caulking as the core height increased. Each section should be water-tight when

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* Civ. and Hydr. Engr., New York City.

† Received by the Secretary, April 27th, 1922.

in place and have an iron ladder on the inside, with one or more narrow shelves, suitable for a foothold. Depending on the length of the section, there should be one or two openings, 5 or 6 in. in diameter, over which a short cell holder or frame of metal should be riveted and made water-tight. The holder should project only 2 or 3 in. The cell itself would have two walls of different material, the outer one of durable rubber or canvass, reinforced by an added thickness at the center and held to the cell frame by a water-tight connection, and the opposite or inner wall would be of strong, clear glass fitted securely in the holder and carrying a short threaded tube. An observer would have good footing in the mast and with a pressure gauge and a small air-pump could force the outer cell wall against whatever pressure there might be, watching the movement through the glass disk. The pressure could be noted and also the return motion of the opposite wall or diaphragm as the air pressure was permitted to decrease. This operation could be repeated several times to obviate instrumental error and the results from another cell below or above could be used as a check.

The vertical pressure could be ascertained by making a very short bend in a cell frame, and having the opening for the cell holder elliptical, to permit of direct observation. When the dam was completed and the top of the mast sealed, an opportunity would still exist to examine the cells and record the resistance to pressure. A number of years might pass before the cell wall would fail, especially if one or two were to be made like a piston of more permanent material; and after that samples of the core could be secured. One mast might be regarded as satisfactory, if material of inferior quality was to be deposited around it, that is, it would be natural to conclude that if the poorer part of the fill was shown to be safe against movement, the better part would be safe. The estimated cost of an apparatus of this kind might be compared with the cost as conducted at one or more of the dams named in the paper.

In massive construction in which there was danger of lateral motion of core material, parts of a mast could be used from a raft carrying a suitable framework and equipment for thrusting down and lifting up a section of reasonable length. This could be used at more than one place in the pool. It might result in the abandonment of cell construction and the use of a plain plunger of appropriate size and weight that could be rapidly settled or lifted while the stresses in the control apparatus were recorded and the character of the material thereby estimated.

THOMAS H. WIGGIN,* M. AM. SOC. C. E. (by letter).†—This paper records the results of observations and experiments on five ably constructed hydraulic-fill dams. The use of Goldbeck cells for observing the vertical and horizontal pressures in the cores makes the record unique and it is to be hoped will mark the beginning of a new era in the study of hydraulic-fill dams, which have been under a heavy cloud since the accidents at the Calaveras and Necaxa Dams.

The writer visited the Gatun Dam in 1910, during its construction, and recalls the doubts then expressed by the Division Engineer, based on his

* Cons. Engr., New York City.

† Received by the Secretary, May 8th, 1922.

tests, as to whether the core would ever solidify. The exceedingly flat slopes of that dam made the question of the consolidation of the core relatively unimportant. However, it would be valuable to have the Gatun data added to this discussion.

In 1919, the writer inspected the San Pablo Dam, then partly constructed, and made some computations on various assumptions for John R. Freeman, President, Am. Soc. C. E., who had been consulted with respect to the dam. A more indeterminate problem than these of hydraulic-fill dams can not well be imagined. The uncertain factors are:

(*a*) Pressure of the core, which may be anywhere from 0.8 to 1.6 times the pressure of water of equal depth.

(*b*) Coefficient of friction of the retaining embankments which may be anything from 0.2 to 0.8, probably in this case nearer the lower limit than the higher, particularly for certain decomposing argillaceous rock where located below the line of saturation.

(*c*) Position of line of saturation on down-stream slope, reducing the weight of the embankment to which the coefficient of friction would be applied, as a factor, in determining resistance to core pressures.

(*d*) Level of water up stream, which affects not only pressures from the core, but also weight of material, due to submergence.

(*e*) Proper factor of safety which might be assumed as anything from 1.5 to 3.

An indefinite number of possible designs can be computed with slopes varying from about 1 on 1 for the most favorable assumptions, a factor of safety of 1.5 to about 1 on 15 for least favorable assumptions, and a factor of safety of 3. Added material beyond these slopes is necessary where the core at the base is wider than the embankment at the top of the core, since, in this case, a part of the embankment is floated on the core.

Probably in no other branch of hydraulic construction is the element of judgment greater. The need for economy in first cost contends strongly with the moral and economic necessity for safety, and the engineer's position is not a comfortable one, particularly when the physical properties of the available materials have special elements of doubt.

Only an accumulation of such observations and records as those contained in the author's paper will reduce these uncertainties and furnish reliable constants for safe design, not to mention constants for the more refined determinations as to how far it will pay to waste fines, in order to reduce core pressures and hence be able to reduce the size of embankments.

Experimental data on cores will be of limited value in design unless reliable methods of classifications of core material can be devised. Mechanical analysis giving the size of the grain is the only method used thus far and probably gives the most important single criterion. Graphs are more easily followed than tables of analyses and a combination graph showing complete analyses of all core material tested by the Miami District and other observers would be of great value. The need of such data is referred to subsequently, in connection with certain cores.

Experimental data are also needed on the friction of embankment material. It is just as necessary to know the available resistance as to know the dis-

rupting pressures. The San Pablo experiments* made by G. W. Hawley, M. Am. Soc. C. E., at the suggestion of Allen Hazen, M. Am. Soc. C. E., are the only ones known to the writer. They were on 14-in. cylindrical sections. At least, some experiments on much larger sections, with comparative tests on small sections of the same material, are needed before placing too much faith in the small-scale experiments. The effect of moisture on coefficients of friction is another phase requiring tests, and the effect of partial suspension of material by water below the line of saturation adds to the complexity of the problem.

The author gives stimulus to the discussion begun with an earlier paper,† as to the degree of coarseness of core material required in order that consolidation may proceed promptly enough to permit lightened design of embankments. Mr. Hazen suggests an effective size of 0.01 mm. (that is, 10% to be finer than 0.01 mm.) as fine enough to insure water-tightness, coarse enough to drain, and demonstrated at San Pablo to be practically attainable (although, in the writer's opinion, with much wastage of fines). In his paper, Mr. Hazen contends that the ordinary cores, which he found to have generally an effective size of about 0.002 mm., do not consolidate much in the comparatively short time during construction.

Mr. Paul believes the Miami cores to have consolidated satisfactorily, although much finer than 0.01 mm. He concludes that "a fairly high percentage of extremely fine material in the core is not objectionable, provided the material is properly graded."

He does not use the water-filtration term, "effective size", but the analyses of the Miami cores in Table 2‡ show 22% on the average finer than 0.005 mm., and this is probably not far from having 10% finer than 0.002 mm. In other words, the Miami cores seem to be of about the same fineness at the 10% point as the cores of the much discussed Western dams. The author mentions analyzing cores of these other dams, and in this connection the graphs showing all the complete analyses that are available are required, as explained previously. In fact, such a compilation is needed to understand the author's conclusion, that proper gradation is an offset for a considerable percentage of fines.

The writer has been interested in pursuing further, as well as may be without complete analyses, the evidence as to what real difference existed between the material in the Miami cores and that in cores of Western dams.

As to penetration tests, a 6-in., cast-iron ball sank in the Calaveras core from 50 to 60 ft. at the maximum and in the Miami cores only 16 ft. Similarly, a 1½-in. pipe, pushed down by two men, penetrated 80 or 90 ft. at Calaveras and only 30 ft. at Miami.§ However, Mr. Hazen, in commenting on these records, stated his understanding that, at the time of the great slip, penetration in the Calaveras Dam was no greater than in the Miami dams. This evidence is not very conclusive as to showing differences in the core material.

* *Transactions*, Am. Soc. C. E., Vol. LXXXIII (1919–20), pp. 1728 and 1818.

† "Hydraulic-Fill Dams", by Allen Hazen, M. Am. Soc. C. E., *Transactions*, Vol. LXXXIII, (1919–20), p. 1713.

‡ *Proceedings*, Am. Soc. C. E., March, 1922, p. 457.

§ *Transactions*, Am. Soc. C. E., Vol. LXXXIII (1919–20), pp. 1797 *et seq.*

As to the appearance of the exposed cores, those at Calaveras and Necaxa were firm after they ceased to move. Those at the Miami dams were firm when exposed at depths of 30 ft. There is something peculiar, as was stated in the discussion on Mr. Hazen's paper, previously mentioned, in the apparent dynamic fluidity which comparatively firm substances have when once cohesion or frictional stability is overcome and they begin to move. It may be that the Miami cores, if started at greater depth, might have shown mobility in the superimposed parts.

As to comparative pressures exerted by the cores of the Calaveras and Necaxa Dams and the Miami cores, unfortunately, one is reduced entirely to speculation in the case of the former two, not having Goldbeck cell records as in the latter case. Mr. Hazen notes* a coefficient of friction of 0.2 for the Calaveras embankment, which was pushed out. This assumes the core to be a fluid of its actual weight. The writer's figure using similar assumptions was 0.3, evidently showing a different section assumed from the records of the slip. D. C. Henny, M. Am. Soc. C. E., computed a maximum coefficient of 0.7 for the same dam.† The writer's figures for the Necaxa Dam were about 0.2 for the theoretical section and 0.6 for the actual worst section, as described by one of the constructing engineers.

From the Goldbeck cell indications, the Miami cores had horizontal pressures on the average such as would be due to a fluid weighing about 50 lb. (Fig. 6)* to 70 lb. (Fig. 4)‡ per cu. ft. If the Necaxa core at failure had exerted no greater pressure than these Miami pressures, the coefficient of friction at the worst section would have been 0.3 to 0.4 and the Calaveras coefficient correspondingly 0.15 to 0.20 (or 0.35 to 0.50 by Mr. Henny's results). It seems doubtful if failure would have occurred at these figures, which argues that the pressures in the Necaxa and Calaveras cores were probably higher than the pressures indicated in the Miami cores by the Goldbeck cells.

On the other hand, even if the Miami cores had exerted a pressure equal to a fluid weighing 100 lb. per cu. ft., the embankments would not have been breached unless their coefficients of friction had been less than about one-third, which seems improbable for well-drained gravel. The well-nigh perfect control of core widths eliminated at the Miami dams the greatest element in the failure of other dams.

Considering the Goldbeck cell indications, it may be possible to learn something about them from the internal evidence of the records themselves and by studying limits of possible errors. Mr. Hazen has suggested that the reaction from the small isolated area of the cell might be carried by a pyramid of earth, as is the case in small area tests of the bearing value of soils. This is undeniably possible but, as has been stated by the author, would cause the Goldbeck cell indications to be too high—an error on the safe side in the study of core consolidation, and an error tending to a minimum the more fluid the core. The small deflection, namely, 0.0001 in., required to break the electrical contact, favors accuracy; studies of soil elasticity would bear on the question.

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* *Transactions*, Am. Soc. C. E., Vol. LXXXIII (1919–20), p. 1728.

† *Ibid*, pp. 1760–1761.

‡ *Proceedings*, Am. Soc. C. E., March, 1922, pp. 464 and 461.

The most direct internal evidence as to the Goldbeck cell indications should be that relating to vertical pressures. These pressures are presumably determined by the weight rather than the degree of solidification of the superimposed material, and the weight is fairly well known. The writer has converted the vertical pressures given in the author's Figs. 4 and 6 into average weights per cubic foot of superposed wet core matrial, as shown in Table 3.

Date.	Depth in, feet.	Vertical pressure shown in diagrams, in pounds per square inch.	Equivalent weight of core per cubic foot, in pounds.
	From Fig. 4, Germantown Dam.		
September 10, 1919	12	6	72
September 25, "	18	11	88
October 23, "	25	18	104
November 12, "	29	21	104
December 5, "	33	22	96
January 27, 1920	41	23	80
March 3, "	41	22	77
April 28, "	48	27.5	83
May 20, "	26	20	111
May 20, "	54	30	80
	From Fig. 6, Taylorsville Dam.		
July 6, 1921	24	10	60
July 28, "	33	23	100
October 27, "	59	45	110
November 26, "	70	52	107

The results in Fig. 4 at the Germantown Dam where the trestle installation was used, seem to be erratic, often giving a lesser weight per cubic foot at greater depths, although the average weight should be greater as the depth increases and the water is squeezed out of the lower layers—unless drainage should be so complete as to leave voids unfilled with water, which is unthinkable. It is more plausible to assume the material to be supported in part at times by the wooden trestle. This trestle, if constructed of timbers even as large as 4 in. by 4 in. (not marked on Fig. 4), could take the load in question.

The Taylorsville (Fig. 6) results for vertical pressures are more consistent, 107 lb. per cu. ft. is the weight of saturated earth having about 56% of voids. If the lower material is conceived to have 50% of voids and to weigh 114 lb. per cu. ft. and the top layers to weigh 100 lb. per cu. ft., the average weight would be about 107 lb.

Similar computations of the horizontal pressures show that, whereas those at Taylorsville (Fig. 6) never reached, at any depth, the intensity of hydrostatic pressure, those at Germantown (Fig. 4), above the depth where the curves turn sharply downward, corresponded with the pressure of a fluid weighing 84 to 104 lb. per cu. ft., averaging about 96 lb. At greatest depths, the pressures at Germantown were, curiously, on nearly every date just a little greater than hydrostatic. In general terms, the horizontal pressures at the Germantown Dam were much higher in absolute value, and more so when considered as functious of the vertical pressures, than those at the

Taylorsville Dam. They also showed a sharper reduction at lower depths, but even there did not go as low as those at Taylorsville.

These differences could be explained by assuming (*a*) the existence of a much more fluid core at Germantown (at the trestle) than at Taylorsville (near the wall); (*b*) that the pressures at greater depths at Germantown are reduced by the trestle; and (*c*) that the trestle had more effect on the horizontal than on the vertical pressures.

The writer confesses to some perplexity resulting from all the considerations previously given, as to whether the Germantown core was so much different after all from the Calaveras and Necaxa cores. The question also suggests itself whether the Goldbeck cells in the Taylorsville Dam were placed so as to give representative pressures in the mass of the core; that is, whether this core also might have given high horizontal pressures away from the concrete wall and wasteway. The writer is not disposed to doubt the substantial accord of the Goldbeck cell indications with the actual pressures existing in the core at the place where the cell is located.

The complete mechanical analyses of the Calaveras and Necaxa cores, if available, plotted to one scale with those of the Miami cores, would throw light on these questions, but the writer fears that there may still be more obscure and less easily recognized differences, such as those suggested by studies of colloidal suspension (see, for example, the summary on this subject in the Progress Report of Special Committee on Bearing Value of Soils).* In the future, some one may add a little of a chemical—an electrolyte—to the sluicing water and precipitate core material which otherwise would be unsuitable. Even now, fear of some disturbance of the colloidal condition might well cause distrust of small-scale experiments on core material.

There is left the question of lateral drainage. A small percentage of reduction in the core moisture near the critical point is probably sufficient to increase greatly the stability. Might not such a reduction take place without noticeable wetness at the toe of the slope? Is it harder to conceive of such moisture going laterally than vertically, in either case through thick layers of fine material? Must it not, in any case, go laterally to connect with the springs? The pressure of superimposed material steepens the hydraulic gradient as well for lateral as for vertical escape of water. Impervious, clayey embankments would retard or prevent lateral escape. The San Pablo tests, showing no flow through perforated casing pipes into test borings, are hard to harmonize with the idea of lateral drainage. It is true that the velocity of drainage water would have to be increased greatly to concentrate on the boring and through the still smaller slotted areas. The difficulty of getting water to well strainers in fine sand is one often experienced. With core material, which is several degrees finer than fine sand, practically complete plugging might be conceived as against flow, but it is hard to explain a well standing empty for weeks.

All the arguments for the efficacy of lateral drainage tend to contradict the previous suggestions that high horizontal pressures may have persisted at

* *Proceedings*, Am. Soc. C. E., March, 1922, p. 547.

the Germantown Dam and perhaps at the Taylorsville Dam away from the wall; for conditions favoring horizontal drainage were ideal in the Miami dams. There is still much to learn about the drainage question.

The writer will await with much interest the author's experienced judgment and data on the various academic questions raised. The author and his colleagues on the Miami Conservancy work are to be congratulated on their skillful design and construction and thanked for taking the first steps and pointing the way to the accumulation of real data on core pressures.

MEMOIRS OF DECEASED MEMBERS

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Acting Secretary prior to the final publication.

ELBRIDGE HARLOW BECKLER, M. Am. Soc. C. E.*

DIED AUGUST 26TH, 1908.

Elbridge Harlow Beckler was born at Boston, Mass., on October 16th, 1854. He was graduated from the Maine State College of Agriculture and Mechanic Arts at Orono, Me., in August, 1876, with the degree of Civil Engineer. Previous to entering college, he had completed a course at Maine Wesleyan Seminary, Kents Hill, Me., where special attention to mathematics and some experience in surveying, enabled him to complete the four-year engineering course in two years.

In 1877, having spent a few months in teaching, Mr. Beckler went to Minnesota to engage in railway construction, but as business conditions at that time were unfavorable, he was compelled to take other work—teaching, farming, surveying, and map-making—during the next two years.

From May 17th to December 24th, 1879, he served as Transitman on location, and Assistant Engineer on construction, on the St. Paul, Minneapolis, and Manitoba Railway, between Fergus Falls and Barnesville, Minn. From March 15th to July 1st, 1880, he was employed as Transitman on location, on the Yellowstone Division, for the Northern Pacific Railroad, and from July 1st, 1880, to January 5th, 1881, he was Assistant Engineer in charge of a party on location, for the same Company.

Mr. Beckler was engaged as Assistant Engineer on Location on the Rocky Mountain Division of the Northern Pacific Railroad, from March 15th, 1881, to February, 1882, and from the latter date until January 24th, 1884, he was Resident Engineer on Construction. This work covered 41 miles and included the Bozeman Tunnel, 3 610 ft. long.

From April 1st to September 1st, 1884, Mr. Beckler served as Division Engineer on the Canadian Pacific Railway, along Kicking Horse River, on the western slope of the Rocky Mountains. This work included a few miles of grading and the construction of several wooden bridges. From September, 1884, until January, 1886, he was Resident Engineer on Construction of the St. Louis River Bridge, for the Northern Pacific Railroad, between Duluth and West Superior, Minn.

On January 6th, 1886, Mr. Beckler was appointed Resident Engineer on Location and Construction for the Montana Central Railway, which position he held until December, 1886, when he was made Assistant Chief Engineer, serving as such until November, 1887. This was the beginning of the Great Northern Extension to the Pacific Coast. In 1889, he became Chief Engineer, in charge of the entire work from Central Montana to Puget Sound.

* Memoir compiled from information on file at the Headquarters of the Society.

In addition to a record for efficiency and economy in the accomplishment of this work, which has seldom been equalled, he secured a route through the main range of the Rocky Mountains, with lower gradients than any other transcontinental line. The location for most of the distance was through an unexplored and mountainous country, making the problem exceedingly difficult, but the entire distance of 818 miles was completed in a little more than two years from the time construction work was inaugurated.

In 1893, Mr. Beckler moved to Chicago, Ill., where he was engaged as Consulting Engineer on many projects, among which was the construction of a narrow-gauge railway in Arizona for the United Verde Copper Company.

From 1895 until 1902, he was in the service of Winston Brothers, Contractors, and on March 1st, 1902, at the time of the organization of the Company as a Corporation, he became a Stockholder and a Director.

He died suddenly of cerebral hemorrhage on August 26th, 1908, at the West Portal Camp of the St. Paul Pass Tunnel, in Shoshone County, Idaho, where he was engaged on work in connection with the Coast Extension of the Chicago, Milwaukee, and St. Paul Railway.

Mr. Beckler was married in 1880 to Miss Mera Rogers, of Richmond, Me., who, with two daughters, survives him.

He was a man of great energy and high ideals, sympathetic, and considerate. He was an Honorary Member of the Montana Society of Civil Engineers and a member of the Western Society of Engineers.

Mr. Beckler was elected a Member of the American Society of Civil Engineers on April 6th, 1892.

FRANK EDWARD BISSELL, M. Am. Soc. C. E.*

Died February 25th, 1922.

Frank Edward Bissell, the son of Thelus Martin Bissell and Ellen Roxana (Stedman) Bissell, was born at Rootstown, Ohio, on August 21st, 1855.

He grew up at South Bend, Ind., his boyhood home, and was prepared for college in its High School. In 1874, he entered Cornell University, taking the course in Civil Engineering, and was graduated in 1878, with the degree of B. C. E. He returned to Cornell for one year of additional study and, in 1879, took the advanced degree of C. E. As an undergraduate, he acquired high standing in his classes and was named by the late Dean E. A. Fuertes, M. Am. Soc. C. E., as Computer for the survey work in his Senior year—the second highest honor. He was an active member of the Zeta Psi Fraternity.

Immediately on his final graduation in June, 1879, Mr. Bissell was employed in the U. S. Engineer Corps as Rodman on construction work for the Missouri River at Atchison, Kans. He was made, successively, Instrumentman and Acting Assistant, and finished this work in December, 1879.

In 1880, he joined the forces of the late Jay Gould, on what afterward became the latter's Southwest System of railroads, with headquarters at

* Memoir prepared by Willard Beahan, M. Am. Soc. C. E.

Fort Worth, Tex. For three years, Mr. Bissell served as Draftsman, Assistant Engineer, and Chief Draftsman. In these positions, he showed himself to be systematic, tireless, of keen perception and an invaluable office man, and these traits he never lost. He afterward became Resident Engineer on maintenance of the Missouri, Kansas, and Texas Division of the Gould lines, and during the next three years was engaged on construction work. From 1885 to 1888, he was engaged on the location and construction of the greater part of the Fort Worth and Denver City Railway, about 350 miles, under the late Gen. Grenville M. Dodge, Hon. M. Am. Soc. C. E., who was then President of that railway. It was pioneer work, and Mr. Bissell won the highest confidence of Gen. Dodge. He had good business qualities; he seldom forgot; he never hesitated; he always worked; he was square, and his honesty was never once in question.

From 1888 to 1891, his work was in the Operating Department of the road he had built—soon afterward controlled by the Union Pacific Company—as Superintendent and Chief Engineer of Construction.

During the following six years, Mr. Bissell was engaged as Engineer for Industries, Superintendent, and Valuation Expert for various companies in the West and Southwest until 1897, at which time he was appointed Engineer for the Receiver of the Wheeling and Lake Erie Railroad, at Cleveland, Ohio, where he remained until 1900, having been engaged on maintenance work and on valuation work of various lines under contemplation of purchase by that Company.

In 1900, at the instance of the late Gen. Dodge, he resigned to accept the position of Chief Engineer of the Arkansas Northern Railway—a line of considerable magnitude which never passed the preliminary stage. Mr. Bissell then took part, as Field Inspector, on the first State valuation of railroads in the United States, namely, that of the State of Michigan, under Dean M. E. Cooley, M. Am. Soc. C. E., of the University of Michigan.

In 1901, he became First Assistant Engineer of the Lake Shore and Michigan Southern Railway, and during the ensuing six years, he did important work as a Staff Officer and also completed the location and built the "Low Grade", a line from Ashtabula to Youngstown, Ohio, the Franklin and Clearfield, and commenced the Cleveland Short Line, around the City of Cleveland, Ohio.

At the inception of the valuation of railroads of the United States by the Federal Government, Mr. Bissell was made Senior Assistant Civil Engineer of the Central District, with an office at Chattanooga, Tenn., in charge of all the field parties in civil engineering work. This work required about six years, and on its completion, he returned to Cleveland, where his family had continued to reside. He then became Chief Engineer of a Contracting Company, which position he retained until seized with his fatal illness. This seemingly unimportant attack was the first illness he could recollect, and his death on February 25th, 1922, was unexpected.

He was married on April 21st, 1886, to Ida Mayer Smith, at Detroit, Mich., who, with their son, Howard Mayer, survives him.

Mr. Bissell was a member of the American Railway Engineering Association, the American Association of Engineers, and the Cleveland Engineering Society, having been a member of the Board of Direction of the latter at the time of his death. He was a Thirty-second Degree, Scottish Rite Mason, Knight Templar, and a Noble of the Mystic Shrine.

Mr. Bissell was an engineer of unusual natural ability. He had had opportunities of learning railroading from its masters in certain pioneer branches, and he had profited by these experiences. He was a worker, a thinker, and earnest in all he did. Honesty was to him inborn; he hated sham, and was no diplomat. He made some enemies, which fact had hindered him at times; but he made his mark on American railroads, and that can never be effaced.

Mr. Bissell was elected a Junior of the American Society of Civil Engineers on April 2d, 1884, and a Member on September 2d, 1891.

WILLIAM HENRY BOOTH, M. Am. Soc. C. E.*

Died November 12th, 1921.

William Henry Booth was born at Rochdale, Lancashire, England, on September 30th, 1854. He was educated at Rochdale Grammar School and Owen's College, Manchester (now the Victoria University), and was apprenticed to Messrs. John Petrie and Company, Ironfounders, at Rochdale.

In 1877, Mr. Booth went to New Zealand and thence to Sydney, New South Wales, where he was employed in the Locomotive Works of the State Railways until June, 1880. He then returned to England, and for the next three years was engaged with the Manchester Steam Users Association, a pioneer body, in the United Kingdom, in the systematic inspection and insurance of steam boilers and engines. He was afterward a partner in a contracting firm which built the sewage outfall tunnel at Rochdale, and a sea outfall sluice at Gibralter Point in Lincolnshire.

In 1887, Mr. Booth went to New York City, but he returned to England in 1889. In 1907, he again visited New York in connection with the utilization of blast-furnace gas.

After assisting with the preliminary engineering work on a subway in the west of London, which scheme failed to obtain Parliamentary sanction, he accepted an appointment with Messrs. Legrand and Sutcliffe, the well known Well and Water Engineers. This engagement gave scope to, and enabled him to enlarge, his knowledge of the geology of England, on which subject he had remarkably detailed information. He particularly studied water-bearing strata, and could give an opinion of the probability of the success of well-boring, and the depth at which water would be found, in any locality, with great accuracy. About 1899, and for about three years following, he was a member of the Engineering Staff of the British Electric Traction Company, mainly engaged on power-house design, but owing to the wide

* Memoir prepared by Henry M. Sayers, Esq.

range of his professional knowledge, his work with that Company included many other subjects.

In the early years of Twentieth Century, Mr. Booth took the leading part in an exploration of the hinterland of Venezuela, *via* the River Orinoco, the territory covered, being prospected for mining and general commercial purposes. If this expedition has not been successful, it is because of difficulties in the way of commerce, which may be generally described as political. When the time comes, his report of this journey should be of great value.

Mr. Booth was a man of wide knowledge. He could not be fairly described as a specialist in any one branch of Engineering, because such a description is altogether too narrow. He had the knowledge and vision which enabled him to see how any engineering question was related to others, and hence to exercise a fully informed judgment which took account of all the relevant circumstances. He was, therefore, an all-round expert, from whom one could rely on obtaining a scheme for anything he studied, which took account of all the conditions, giving proper weight to each.

Mr. Booth's connection with engineering journalism was a long one, his first article appearing in the *English Mechanic* in 1876. He was on the staff of the *Mechanical World* from 1881 to 1887, for four years as Editor. For many years, he contributed to the *Railroad Gazette* and to the *American Machinist*. He was on the editorial staff of the *Electrical Review* (London) for a number of years.

He devoted a great deal of study to the economical utilization of fuel, smoke prevention, the construction of furnaces, especially for steam boilers, and chimneys. He was much interested in fuel economy, and advocated methods for attaining that end, much in advance of contemporary practice, which methods are now recognized as standard.

His last professional work was done in charge of the water supply to the great motor-car repair depot at Slough, where he had the satisfaction of sinking a deep well which struck water-bearing strata within a few inches of the depth which he had estimated.

Mr. Booth was a Fellow of the Geological Society, London. Geology, especially in connection with water supply, was the subject in which he perhaps took the greatest interest, and was most widely known as an expert.

He published several books, among which are the following: "Liquid Fuel and Its Combustion", "Liquid Fuel Apparatus", "Smoke Prevention and Fuel Economy", "Superheat and Superheating", and "Steam Pipes". He was a contributor to Kempe's "Engineers' Year Book" from its earliest issue, and the 1921 edition contains articles from him on—Steam Engines and Boilers; Properties of Gases; Pumps; Cotton Mills; Water Softening; and Well Sinking. He also contributed numerous papers to and lectures before English engineering societies.

Mr. Booth was married in 1877, and is survived by his widow, two sons, and one daughter. He was a truly lovable man, the most loyal of friends, and the most chivalrous of opponents.

Mr. Booth was elected a Member of the American Society of Civil Engineers on July 4th, 1888.

HARRY DEAN BUSH, M. Am. Soc. C. E.*

DIED MARCH 15TH, 1922.

Harry Dean Bush, the son of Austin Ballou and Susan E. (Millard) Bush, was born on April 2d, 1857, in Springfield, Mass., and was descended on both sides from old Massachusetts families of Colonial distinction. He received his preparatory education in the elementary and High Schools of his native city. Later, he attended the Worcester Polytechnic Institute, from which he was graduated with honor, in 1879, ranking second in his class, with the degree of Bachelor of Science.

Mr. Bush entered on his career as a civil engineer in the old R. F. Hawkins Bridge Works in Springfield, Mass., and became, at the end of two years, Bridge Engineer for the Northern Pacific Railroad Company, with headquarters at Portland, Ore. After four years at Portland, he was, for one year, Assistant Engineer in the office of the late George S. Morison, Past-President, Am. Soc. C. E., in New York City, and, for three years, Superintendent of the Bridge Shops of the Dominion Bridge Company, Limited, at Montreal, Que., Canada.

After terminating his connection with the Dominion Bridge Company, Mr. Bush spent a year of travel and study in Europe, and on his return was again associated, for two years, with Mr. Morison, of New York City. He then went again to Portland, Ore., where, for three years, he was Engineer and Superintendent for the contractors who constructed the Bull Run Pipe Line, 24 miles long, for the Portland City Water-Works System, and the steel gates for the Cascade Locks, Columbia River, the largest ever built previous to those for the Panama Canal.

Mr. Bush then became Contractor for the pipe line for the Water-Works System of New Bedford, Mass., and, in 1899, after an absence of ten years, returned to the Dominion Bridge Company as Engineer in charge of the erection of bridges. In this capacity, he had charge of the erection of the Royal Alexandra Bridge, across the Ottawa River, at Ottawa, Ont., Canada. He presented a paper before the Canadian Society of Civil Engineers on the construction of this bridge, for which he was awarded the Czowski Silver Medal, an annual prize given the writer of the paper or article of the highest merit on some phase of engineering.

In 1903, Mr. Bush went to Baltimore, Md., and became Vice-President and Manager of the Baltimore Bridge Company, then recently organized. It was through his untiring energy and devotion that this Company soon acquired a well-deserved reputation of the highest standard, furnishing steel bridges and buildings for the Baltimore and Ohio and other railroads, the notable steel arch bridge over the spillway of the Croton Dam for the New York City Aqueduct Commission, and much work for export, including all the bridges on the Guatemala Railway System, bridges in Costa Rica, sugar-mills in Cuba, and several important contracts for the Isthmian Canal Commission. It was largely as a result of his work that the Baltimore Bridge Company was acquired by the Carnegie Steel Company about 1912, and, as

* Memoir prepared by Joseph E. Lewis, Esq., Baltimore, Md.

a consequence of this new connection, the scope of the plant was greatly enlarged under his continued management.

In the spring of 1911, a new industry was brought to Baltimore from Newark, N. J. This new company was known as the Tube Bending and Polishing Machine Company and was backed financially by Mr. Miner .C. Keith of New York City, the President and owner of the Baltimore Bridge Company. Mr. Bush became President of this new company as well as of the Compressed Copper Company, a subsidiary organization. The Tube Bending and Polishing Machine Company was re-organized later into the Baltimore Tube Company, Incorporated.

Mr. Bush died on March 15th, 1922, at his home in Baltimore, Md., and is survived by his widow, Mrs. Frances Dent Bush.

Mr. Bush was married (first) to Emma F. Witherbee, of Gardner, Mass., who was well known for her musical ability. Mrs. Bush died in 1907, and in 1909, Mr. Bush was married to Frances (Dent) Davis, the daughter of Thomas Dent, of St. Mary's County, Maryland.

Mr. Bush was an engineer of high standing and a business man of no mean ability. Physically, he was compactly and strongly built, of vigorous and alert bearing, kindly countenance, and affable manners. Of genial disposition, he was popular socially and had a large circle of friends. He was pre-eminently a friend of men, especially of young men, and was actively interested in the Young Men's Christian Association. He was a man of sterling qualities, whose word was as good as his bond. It has been said of him that he never missed an engagement and was never late at an appointment. A Democrat in politics, he took a lively interest in all matters concerning the public welfare.

His special tastes were for Science and Mathematics. Mr. Bush was always a great reader and, in the course of his life, collected a large library of essays, romance, poetry, and the drama. His home reading was chiefly outside the field of his work. He was also a lover of music and of culture.

Liberal in his views and true to the traditions of his family, his church affiliation was always with the Universalists or Unitarians. During the last few years of Walt Whitman's life, Mr. Bush was one of his supporters and attended several of the birthday dinners given to the "Good Gray Poet", including the one made famous by the debate between Whitman and Ingersoll on "Immortality."

Mr. Bush was a member of the Engineering Institute of Canada, the Engineers' and Whitehall Clubs of New York City, and the Baltimore Athletic Club.

Mr. Bush was elected a Member of the American Society of Civil Engineers on May 2d, 1888.

FRANK HUDSON CLEMENT, M. Am. Soc. C. E.*

Died February 18th, 1922.

Frank Hudson Clement was born in Philadelphia, Pa., on June 6th, 1853, of Quaker stock. He was educated in the schools of that city, having been graduated from the Lincoln Grammar School.

* Memoir prepared by L. V. Morris, M. Am. Soc. C. E.

From 1869 to 1874, Mr. Clement started on his long and successful career as an employee with Naylor and Company of Philadelphia, manufacturers of iron and steel.

In 1874, he studied the practical end of Civil Engineering and Surveying with Hudson Shedaker, and in October of that year, he entered the employ of the Pennsylvania Railroad, where he remained until January, 1878.

During 1876 and 1877, under Assistant Engineer W. L. Ziegler, the late Stacy B. Opdyke, Jr., M. Am. Soc. C. E., and others, Mr. Clement was engaged on the construction of the stockyards at Philadelphia and of the West Philadelphia Depot, and, in 1877, he was in charge of the construction of the Pittsburgh Depot.

Early in 1878, he joined the ill-fated expedition of the Madeira and Mamoré Railway Company in Brazil. This expedition was the result of a contract made by Messrs. Philip and Thomas Collins, for the construction of a railroad around the falls and rapids of the Madeira and Mamoré Rivers. The party was composed of men, all of whom, in later years, became prominent in various walks of life. The expedition failed, owing to lack of sanitation and inability to transport supplies.

Early in 1879, Mr. Clement entered the service of the Northern Pacific Railway Company as Assistant Engineer and Engineer to the Vice-President, and, in 1880, was Topographical Engineer, under Col. J. T. Dodge, on surveys for the Missouri and Yellowstone Divisions.

In 1881, he was engaged as Engineer in charge of surveys and locations on the Mexican National Railway, and Division Engineer on completion of the Toluca Division. He returned to the United States in 1882, as Division Engineer of the South Penn Railroad, spending four years on surveys, location, and construction.

Later, Mr. Clement returned to the East and, having entered the construction business on his own account, built a part of the New York Aqueduct. On the completion of this work, he went to Cuba with the Cerebro Company to take entire charge of its mines, after which, on returning to the United States, he contracted to build 35 miles of railroad in Maryland.

In 1890, he formed a partnership with Mr. John C. Rogers, of New York City, to build the first Niagara Falls Tunnel for the Niagara Falls Power Company.

Mr. Clement was also associated as a partner, with Mr. Charles F. King, under the firm name of Clement, King, and Company, and after Mr. King's death, he continued the business under the name of F. H. Clement and Company. Until 1906, Mr. Clement and his associates undertook and completed work costing many millions of dollars. It is worthy of note at this time that the contractors for the Madeira and Mamoré Railroad evidently recognized his ability, as they were associated with him in all the larger projects.

Mr. Clement and his associates specialized in heavy railroad construction, so that to-day the Mt. Airy and Sand Patch Tunnels on the Baltimore and Ohio Railroad, the Galitzin and Baltimore Tunnels on the Pennsylvania Railroad, the New York Central (Beech Creek), into Clearfield, Pa., and the

Petersburg Cut-off of the Pennsylvania Railroad, are monuments to his ability.

From 1910 until a year previous to his death, Mr. Clement was engaged in industrial work, principally for the Bethlehem Steel Corporation at Bethlehem, Pa., Steelton, Pa., and Sparrows Point, Md., contributing to the great expansion of that Corporation's plant. During the World War, he built for the same firm a shell-loading plant at Mays Landing, N. J.

Mr. Clement's long and prominent career was the result of elementary training, the overcoming of seemingly insurmountable difficulties, which, in after years, made the detail of his organization and work a simple matter. One of his chief characteristics was his ability to make and retain friends. For thirty-one consecutive years, at his Port-Au-Peck Clambake, were gathered as his guests, intimate friends, the highest exponents of many professions and activities.

In 1885, Mr. Clement was married to Anna Louise Dietz, who survives him.

The character of the man is indicated by his social, fraternal, military, civic, and technical affiliations. His clubs were the Castine Golf Club, of Maine; Royal Societies Club, of London, England; Huddersfield Fish and Game Club, of Canada; Engineers Club of New York; Engineers Club of Philadelphia, Pa.; Art Club, of Philadelphia; New York Athletic Club; National Republican Club, of New York City; Bethlehem Club, of Bethlehem, Pa.; Garden City Club, of Long Island; and the American Cornish Club, of Utica, N. Y.

He was a member of Everett Lodge F. and A. M. No. 524, of Everett, Pa.; Bedford Royal Arch Chapter No. 225, of Bedford, Pa.; and the Masonic Veterans, of New York City. He also belonged to the following military organizations: New Jersey State Rifle Association, of Sea Girt, N. J.; Old Guard, City of New York; First Regiment (Veteran Corps) N. G. P., and Old Guard, Co. K, and Co. A, First Regiment, N. G. P., of Philadelphia, Pa.

He was also a member of the following civic organizations: Madeira-Mamoré Association, of Williamsport, Pa.; Society of Friendly Sons of St. Patrick; and the Contractors Association, of Philadelphia; as well as the following engineering societies: American Institute of Mining Engineers, Franklin Institute, Verein Deutscher Eisenhuttenleute, and the American Concrete Institute.

Mr. Clement was elected a Member of the American Society of Civil Engineers on November 1st, 1862.

WILLIAM TYNDALE JENNINGS, M. Am. Soc. C. E.*

Died October 4th, 1906.

William Tyndale Jennings was born at Toronto, Ont., Canada, on May 19th, 1846. He received his education at the Model Grammar School and at the Upper Canada College in Toronto.

* Memoir prepared by James H. Kennedy, M. Am. Soc. C. E.

Mr. Jennings began his engineering work in 1869 as Assistant on drainage improvements of the Crown Lands of Ontario, under the late T. N. Molesworth, Engineer with the Ontario Government.

In 1870, he entered the service of the Great Western Railway and was engaged in surveying, location, and construction work until 1873, when he was appointed Resident Engineer on Construction of the Air Line Division of that road. Later, he was appointed Resident Engineer of the London and Port Stanley Railway Company and of the Welland Railway Company.

In 1875, Mr. Jennings was made Locating Engineer on the British Columbia Section of the Canadian Pacific Railway, in which capacity, and in addition to other work, he located the present line of that railway through the canyons of the Fraser River. In 1879, he was made District Engineer on the construction of "Section B" of the Canadian Pacific Railway, from Rat Portage to Eagle River, with headquarters at Rat Portage, Ont. On the completion of this work, Mr. Jennings returned to British Columbia as Superintending Engineer on that Section for the Dominion Government.

In 1883, after a year in the East, Mr. Jennings returned to British Columbia as Chief Engineer and Acting Manager of the Construction Company in charge of work on 350 miles of that Section, east from the Pacific Coast, with headquarters at Yale, B. C.

In 1885, he was appointed Chief Engineer of the Detroit Extension of the Canadian Pacific Railway, comprising the section between Woodstock and Windsor, Ont. On the completion of this work which included the construction of the Toronto Wharves from Yonge Street westward, Mr. Jennings was made City Engineer of Toronto, which position he held for one year. During this time, he re-organized the Engineer Department effecting many municipal improvements, among which were the Sherburne Street Bridge and the King Street Subway.

In 1891, he opened an office in Toronto and began private practice as a Consulting Engineer. As Chief Engineer, from 1892 to 1895, he located the line of the "Crow's Nest" Railway. He also had charge of many large projects, among which may be mentioned the construction of electric railway lines, examinations relative to the opening up of vast areas of country to the north and west, for the Canadian Government, and the navigability of various rivers. He continued his private practice until his death on October 4th, 1906.

Mr. Jennings was a member of the Institution of Civil Engineers of Great Britain, of the British Association for the Advancement of Science, the Imperial Institute, and the Canadian Society of Civil Engineers, of which he was President in 1899. He served for several years as Examiner in Civil Engineering subjects for the University of Toronto and was always enthusiastic for the advancement of engineering education.

He was married in 1876 to Miss McKay, daughter of the Registrar of the County of Elgin, who died in 1887. He was survived by one son, Gordon T. Jennings.

Mr. Jennings was elected a Member of the American Society of Civil Engineers on April 2d, 1884.

JOHN RICHARD SAVAGE, M. Am. Soc. C. E.*

Died February 25th, 1922.

John Richard Savage was born in Philadelphia, Pa., on April 17th, 1869. He was graduated from the University of Pennsylvania in 1889, receiving degrees of Bachelor of Science and Civil Engineer.

In May, 1889, Mr. Savage entered the employ of the Pennsylvania Railroad as Rodman and Levelman in the Chief Engineer's Department, where he served until October, 1890, resigning to accept a position under Capt. T. W. Symons, Corps of Engineers, U. S. A., with headquarters at Portland, Ore.

Mr. Savage continued in the service of the Government, as Assistant Engineer until May, 1895, during which period he had charge of reconnaissances, hydrographic surveys, and harbor improvements in the Puget Sound country. In May, 1895, he was appointed Engineer of the Seattle and Lake Washington Company, a corporation the plans of which, in connection with the reclamation of tidal lands adjoining Seattle, Wash., and the cutting of a canal from Puget Sound to Lake Washington, contemplated the present development.

In August, 1897, Mr. Savage again entered the employ of the Pennsylvania Railroad, under the Engineer of Branch Lines, and was engaged on the construction of the Norfolk and Portsmouth Belt Line Railroad, of piers at Norfolk, Va., and of a part of the Southwest Pennsylvania Railroad extension in Fayette County, Pennsylvania. In 1899, at the close of the Spanish-American War, the Federal Government appealed to the Pennsylvania Railroad for an engineer to complete the construction of railroads and docks in the environs of Havana, Cuba, and Mr. Savage was selected for this task.

From October, 1900, to July, 1901, he was engaged in making surveys for a proposed railroad through Lebanon Valley from Cornwall to Highspire, Pa., a new outlet for the Cornwall ore banks. In August, 1901, he entered the employ of the Lackawanna Iron and Steel Company, later known as the Lackawanna Steel Company, and continued with that firm during the construction of the new plant at Buffalo, N. Y., holding the positions of Superintendent, Assistant to the Vice-President, and Assistant General Superintendent.

On April 1st, 1904, Mr. Savage was appointed Chief Engineer of the Long Island Railroad and from that date until October, 1917, he was in direct charge of the large and diversified engineering and construction projects on Long Island, the most important being the Jamaica Improvement, which was an extended elimination of grade crossings, and the construction of the most intensive passenger transfer facilities in the United States, all accomplished during train operation, the grade-crossing elimination and revision of the main line, connecting this Transfer Station with Sunnyside Yard of the Pennsylvania Terminal, and the changes in grade through Flushing. On October 1st, 1917, he was appointed General Manager of the Long Island Railroad succeeding Col. James A. McCrea who went to France with the American Expeditionary Forces.

* Memoir prepared by L. V. Morris, M. Am. Soc. C. E.

During the period of Federal control, Mr. Savage was General Manager of the Long Island Railroad, under Mr. Ralph Peters, Federal Manager. With the re-organization, on March 1st, 1920, at the end of Federal control, the position of General Manager was abolished, and Mr. Savage was made General Superintendent with practically the same duties.

Mr. Savage was married on June 7th, 1904, to Miss Elspeth Mona Murray who, with three children, survives him.

Mr. Savage's military and gentlemanly personality appealed to all who knew him. His outstanding characteristic was that of minute attention and interest in the details of design, construction, operation, and accounting. He was endowed with the faculty for thorough investigation and analysis and a clear, concise, and careful expression of conclusions. His untiring devotion to his duties, his ever listening ear, his personal interest as adviser to all members of his staff, make his loss the more pronounced professionally as an engineer and humanly as a man.

To few men in railroad life was it given to hold the respect and affection of his fellow officials, as well as that of the employees generally, to the degree enjoyed by Mr. Savage. Blessed with a kindly disposition, coupled with a broad and philosophical view of life, he was equipped to handle big problems successfully and to win the ardent co-operation of the men with whom he worked so loyally.

Mr. Savage was a member of the following clubs and technical associations: Garden City Club and Cherry Valley Club, Garden City, N. Y.; Huddersfield Fish and Game Club, Canada; University of Pennsylvania Club of New York; Psi Upsilon Fraternity; Engineering Alumni Society of the University of Pennsylvania; General Managers' Association of New York; and the American Railway Engineering Association.

Mr. Savage was elected a Member of the American Society of Civil Engineers on June 7th, 1905.

HORACE EDWARD STEVENS, M. Am. Soc. C. E.*

Died February 14th, 1922.

Horace Edward Stevens was born at Underhill, Vt., on December 14th, 1848, his father, Luther M. Stevens, coming from Wellesley, Mass., and his mother, Mary A. Catlin, from Burlington, Vt. His early days were spent on a farm and about a small saw-mill operated by his father at the foot of Mount Mansfield in his native State. In 1862, his parents moved to Burlington, in order to give their children (three sons and three daughters) the better educational advantages which that city afforded. He was graduated from the Burlington High School in 1866, and in the fall of that year entered the Engineering Department of the University of Vermont, from which, with Henry H. Douglas, he was graduated in 1870. They were the first to receive the degree of Civil Engineer from that institution. Like many other boys of those days, Mr. Stevens worked his way through the University, earning

* Memoir prepared by L. S. Oakes, Assoc. M. Am. Soc. C. E.

his board and lodging by doing chores about the home of his landlady, and his spending money during vacation periods by teaching school.

In September, 1870, he went to St. Paul, Minn., and secured a position in the Engineering Corps of the Northern Pacific Railway Company, remaining until October, 1873. During 1870 and 1871, he was on the location and construction of the lines of that railway between Northern Pacific Junction (now Carleton) and Moorhead, Minn. The following year, and in the early part of 1873, his work took him along the lines of that road, through what was then the Territory of Dakota, to the Missouri River. In March, while in camp on the James River, he was ordered, with a party of six men and teams, to drive with the greatest speed across country to the projected crossing of the Missouri, to stake out claims and secure "squatters' rights," for the benefit of the Railroad Company, before the arrival of a party of land speculators, already on their way. The race was a hard one, through snow and blizzards for seven days, first, one party forging ahead, then the other—both arriving at the site of the proposed crossing in the early morning of April 1st, the engineers on foot, their horses worn out and their conveyances abandoned. In the gray of the dawn three of them drove the claim stakes, while the others, with rifles in hand, held the "enemy" at bay. These stakes marked the beginning of Bismarck, the capital city of North Dakota.

In June, 1873, Mr. Stevens was transferred to an expedition detailed to make a survey west of the Missouri River. The engineering party consisted of Gen. Thomas L. Rosser, in charge; A. O. Eckelson, Reconnaissance Engineer; Montgomery Meigs, M. Am. Soc. C. E. (later, U. S. Engineer at Keokuk, Iowa), third in charge; Hubert W. Reed, Transitman; H. E. Stevens, Head Leveler; E. T. Winston, Second Leveler; and F. G. Winston, Third Leveler. A detachment of Government troops under Gen. Stanley, consisting of about 900 Infantrymen, about 800 of the Seventh Cavalry under Col. (later, Gen.) Custer, 100 Indian scouts, and a supply train, accompanied them.

Starting from Fort Abraham Lincoln, across the river from Bismarck, the party went westward, following closely the subsequently located line of the Northern Pacific Railway, to the confluence of Cedar River with the Yellowstone, about 13 miles above the present site of Glendive, Mont. Crossing the Yellowstone, they continued westward to Pompey's Pillar; thence, northerly, across the Divide to the Musselshell, and down that stream; thence, eastward, to the Yellowstone, crossing near Cedar River, and back to Fort Lincoln, having made an average progress of about 15 miles per day of completed survey, with a maximum of 25 miles. The news of the failure of Jay Cook and Company, the financiers and backers of the Northern Pacific, which attended the panic of 1873, threw the members of the party into a state of mind which was only relieved on their arrival at the headquarters of the Railroad Company, at Brainerd, Minn., where, to their great relief, they found salary checks in full awaiting them for their season's services.

From 1873 to 1881, Mr. Stevens was in the employ of the United States River and Harbor Department. His first work was in connection with the preservation of St. Anthony Falls at Minneapolis, Minn., where a tunnel was constructed from bank to bank under the crest of the cataract, which later

was filled with concrete, thus preventing the disintegration of the soft sandstone bed of the Mississippi at that point and halting the recession of the Falls. Later, he made surveys of the Mississippi River between Grand Rapids and St. Cloud, Minn., of the Yellowstone from its mouth to near Miles City, Mont., and of the Missouri from Bismarck to a point near Helena, Mont. He was in camp with a party on Cow Island on the Missouri River, near Judith, Mont., when, in 1877, Chief Joseph and his band of Nez Perces Indians, on the warpath, crossed that stream. Neither party knew of the presence of the other, and no one was molested.

In 1882 and 1883, Mr. Stevens became interested in and was employed by Robinson and Cary, dealers in machinery and contractors' supplies, in St. Paul, Minn. During 1884 and 1885, he did his first contract work—a section of the aqueduct for the St. Paul Water-Works, and some Government harbor work on the Mississippi at Stockholm, Wis.

In 1886, he became Superintendent for Shepard, Siems, and Company, on the construction of the Great Northern Railway between Devil's Lake and Minot, N. Dak. In 1887 and 1888, he was employed as Superintendent of Construction of the "Soo" Line, near Escanaba, Mich., for Henry and Balch. From 1889 to 1893, he built a reservoir and a gas tank in Duluth, Minn., as well as a sewer, water-works, and the London Road at Lakeside, in that city. In 1894 and 1895, he was Water Commissioner of the City of St. Paul, and, in 1896, he constructed water-works at Superior, Wis., and Brainerd, Minn. During 1897, he was President of the Water-Works Company at Bozeman, Mont.

In the early part of 1898, he was selected by the late Lyman E. Cooley, M. Am. Soc. C. E., Engineer, of Chicago, Ill., as one of a committee of engineers and contractors to go over the proposed Nicaragua Canal route for the purpose of investigating and determining the possibilities and structural feasibility of that project. They left New York City, in January, going first to Panama, where the French were still operating, thence to Nicaragua, where they traversed the line of the proposed canal across that country to the Pacific.

In 1898, he began his association with Winston Brothers, Contractors, of Minneapolis, Minn. During that year and the one following, he was in charge for that Company of a grade revision on the Northern Pacific Railway between Jamestown and Bismarck, N. Dak.; in 1900, of construction on the Cleveland, Lorraine and Wheeling Railway, between Elkhart and Grafton, and between Elyria and Lorraine, in Ohio; and, in 1901, of grading and yard improvements on the Chicago and North Western Railway, at South Omaha, Nebr. When Winston Brothers incorporated in 1902, as Winston Brothers Company, Mr. Stevens became a Stockholder and Director, and from 1914 to 1920, was Vice-President of the Corporation. In addition to other services for that Company, he had charge of additional work on the Cleveland, Lorraine and Wheeling, between Columbia and Navarre, and between Canal Dover and Uhrichsville, in Ohio; track depression in Milwaukee, Wis., and a short line through Sheboygan, Wis., of the Chicago and North Western; construction of the Indiana Harbor Railway, between St. John and Kentland,

Ind.; and a change of line on the Chicago, St. Paul, Minneapolis and Omaha Railway between Minneopa and Lake Crystal, Minn. He also had much to do, from 1907 to 1909, on the reconstruction of the Northern Pacific between Garrison and Missoula, and on a portion of the new Pacific Coast Line of the Chicago, Milwaukee and St. Paul Railway, in Montana, and, later, on a portion of the new line of the Chicago and North Western between Wyeville and Milwaukee, Wis.

He had been in failing health for ten months previous to his death which occurred on February 14th, 1922, at his home in St. Paul, Minn.

Mr. Stevens was married on December 12th, 1893, to Mrs. I. M. Armstrong of St. Paul, who died in 1912. He was a member of the Chicago Engineers' Club, of the Engineers' Society of St. Paul, and, during 1919, was President of the Minnesota Joint Engineering Board.

He was interested in and well informed on many lines of thought outside his profession, had traveled extensively in Europe and the Orient, as well as in his own country, and kept in touch with the progress of events and of developments in the world at large. He was extremely careful and painstaking in whatever he undertook and, although he was on time in his work, he estimated thoroughness and accuracy as of greater importance than speed.

He was known to his business associates as a man of sterling character, of the highest integrity, of pleasing personality, and of excellent business judgment. Although his tendency, due largely to heredity and early environment, was in the direction of extreme conservatism, Mr. Stevens was one who had assimilated the "association idea", and who could and did submerge his individual opinion in business matters in the composite conclusions of the group of his co-workers.

He was, however, unusually self-contained and reserved, which characteristics resulted in his having few intimates. Those who were admitted to terms of intimate friendship recognized in that intimacy a fine privilege, a source of pleasure and profit, through which "he, being dead, yet speaketh."

Mr. Stevens was elected a Junior of the American Society of Civil Engineers on November 1st, 1876, and a Member on April 4th, 1888.

JOSEPH WOOD, M. Am. Soc. C. E.*

Died March 4th, 1922.

Joseph Wood, the son of Isaac H. and Elizabeth (Cooper) Wood, was born at Haddonfield, N. J., on June 5th, 1846. He was educated in Philadelphia, and was graduated in 1864 from the Polytechnic College of the State of Pennsylvania as a Civil Engineer.

Mr. Wood began his railroad career in October, 1864, as Rodman on the construction of the Connecting Railway, Philadelphia, Pa. In 1867, he was appointed Assistant Engineer, having entire charge of the work which included the bridge over the Schuylkill River, near Fairmount Park. In 1865, he also had charge of finishing a tunnel on the Junction Railroad, Philadelphia, and

* Memoir compiled from information furnished by J. J. Turner, Vice-Pres., Penn. Lines W. of Pitts., Pittsburgh, Pa., and on file at the Headquarters of the Society.

building an extension of the Pennsylvania Railroad to Greenwich Wharves, Delaware River, including the construction of three wharves. During 1868, he made surveys for the location of the Columbia and Port Deposit Railroad in Pennsylvania and Maryland, and located and built part of the South Mountain Railroad from Carlisle to Pine Grove Furnace, Pa.

In 1869, Mr. Wood entered the service of the Northern Central Railway Company as Resident Engineer. In this capacity, he was engaged on the construction of the engine houses and shops at Marysville, Pa., and also the rebuilding of the Dauphin Bridge over the Susquehanna River. In May, 1872, he was appointed Resident Engineer of the Baltimore and Potomac Railroad, then being constructed, and Engineer of the Northern Central Railway.

In May, 1878, Mr. Wood was appointed Assistant Engineer in the Motive Power Department of the Pennsylvania Railroad at Altoona, Pa. This was the beginning of his career with the Pennsylvania Company with which he was connected until his death and which he served so ably. In December, 1881, he became Superintendent of Motive Power for the Lines West of Pittsburgh, and in November, 1887, was appointed General Superintendent of Transportation.

Mr. Wood became General Manager in March, 1890, and was elected Fourth Vice-President in January, 1896. He was afterward promoted to the offices of Second and First Vice-Presidents, successively, having been elected as First Vice-President in January, 1907.

In April, 1913, he was elected a Member of the Board of Directors of the Pennsylvania Company, and served also as a Director of the Pittsburgh, Cincinnati, Chicago and St. Louis Railway Company, and of many of the subsidiary companies in the Pennsylvania System West of Pittsburgh. Mr. Wood severed his connection with the Lines West of Pittsburgh in February, 1914, after nearly fifty years of service. He had served as a representative of the Pennsylvania Company on the directorates of other companies in which the System was interested, and at the time of his death on March 4th, 1922, he was a Member of the Board of Directors of the Norfolk and Western Railway Company and Chairman of its Finance Committee.

Although most of the active years of his life were spent in the service of the Lines West of Pittsburgh, he thoroughly understood the affairs of all the lines connected with the Pennsylvania System.

Having begun his service in the early days of railroading, and having had experience in all its branches, Mr. Wood was an authority on railroad management, and also in the fields of commerce, industry, and finance. He was firm in his convictions, but not prejudiced, always willing to listen courteously to the opinions of others. He was loyal, conscientious, and efficient in his work, through which qualities he attained success in his official career. Mr. Wood was greatly respected and esteemed by his friends and business associates, and his loss will be felt by all with whom he came in contact.

In October, 1874, he was married to Miss Jennie E. Boas, who died on December 14th, 1913.

Mr. Wood was elected a Member of the American Society of Civil Engineers on April 1st, 1874.

PAPERS IN THIS NUMBER

"LOCOMOTIVE LOADINGS FOR RAILWAY BRIDGES." D. B. STEINMAN.

"TRANSMISSION OF PRESSURE THROUGH SOLIDS AND SOILS, AND THE RELATED ENGINEERING PHENOMENA." GEORGE PAASWELL.

"FLOOD PROBLEMS": A Symposium.

"THE NATIONAL HOUSING PROBLEM": A Symposium.

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PROCEEDINGS

OF THE

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OF

CIVIL ENGINEERS

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AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

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MINUTES OF MEETINGS
OF THE SOCIETY

June 7th, 1922.—The meeting was called to order at 8:10 P. M.; President John R. Freeman in the chair; Elbert M. Chandler, Acting Secretary; and present also, 80 members and guests.

The minutes of the meeting of May 3d, 1922, were approved as printed in *Proceedings* for May, 1922.

The election of the following candidates on May 8th, 1922, was announced:

As Members

Alvin Barton Barber, New York City
Lawrence Byron Barker, Chicago, Ill.
Garwood Ferguson, Paterson, N. J.
Amory Prescott Folwell, New York City
Orloff Henry, New Orleans, La.

Carl Lathrop Howell, Buffalo, N. Y.
John Roberts Peavy, Hartsville, S. C.
Loring Harvey Provine, Urbana, Ill.
George Everett Rex, Kansas City, Mo.
John Jefferson Richey, College Station, Tex.
Harvey Arthur Van Norman, Los Angeles, Calif.
Harry Walton, Rangoon, India
Alexander Raffen Webb, Manila, Philippine Islands
Reginald Wentworth Wells, Bogota, N. J.

As Associate Members

Asa Columbus Baldwin, Seattle, Wash.
William Henry Barton, Jr., Philadelphia, Pa.
John Baptist Bertrand, Omaha, Nebr.
Clifford Allen Betts, Denver, Colo.
Max Bloch, South Charleston, W. Va.
George Lewis Campbell, Salina, Kans.
Gaylord Church, Astoria, Ore.
Raymond Gillespie Church, Bozeman, Mont.
Merlin Cross Crawford, Ennis, Tex.
Carl Mathias Duff, Lincoln, Nebr.
Carl Ray Duncan, Morgantown, W. Va.
Hermon Martin Freeman, West Orange, N. J.
Samuel Garmezy, Manila, Philippine Islands
Edmond Hannon Gibson, Richmond, Va.
Joseph Halpern, New York City
Frank Herrmann, Oklahoma, Okla.
Laurence Brackett Hoyt, Melrose, Mass.
Eugene Samuel Jaccard, San Francisco, Calif.
Kirby Viglini Jones, Yellow Springs, Ohio
Justin Thomas Kingdon, Cheyenne, Wyo.
William Henry McCaully, Winnetka, Ill.
Gayle McFadden, West Palm Beach, Fla.
Allen Shelly McMaster, Santa Anna, Tex.
Joseph Albert Marck, Brooklyn, N. Y.
Thomas Yancey Milburn, Durham, N. C.
Frederick William Mills, Washington, D. C.
John Russell Montague, Montreal, Que., Canada
Charles James Moritz, Effingham, Ill.
Herbert Erskine Nicol, Milwaukee, Wis.
George Frederick Orthey, Brooklyn, N. Y.
Turner Langbridge Pearson, Spanish Town, Jamaica
Albert Lincoln Pfau, Jr., St. Petersburg, Fla.
Sol Pincus, New York City
James Randal Pollock, Flint, Mich.
John Waller Pritchett, Austin, Tex.
Joseph Flading Robinson, Washington, D. C.

Franklin William Saunderson, Cedarhurst, N. Y.
James Ferris Seiler, Cheyenne, Wyo.
Gustavus Sailer Simpson, Atlantic City, N. J.
Philip Stanwood Strout, Wollaston, Mass.
Samuel Fletcher Tapman, New York City
Alfred Henry Wieters, Waubay, S. Dak.
Ernest Grant Willemin, Ann Arbor, Mich.

As Affiliates

Louis Brownlow, Petersburg, Va.
Orley Hanson Dawson, Detroit, Mich.
John Alexander Macdonald, Hartford, Conn.
James Pinnell, New York City

As Juniors

Adolph Robert Knodel, New York City
Meyer Alvin Lippman, Brooklyn, N. Y.
Charles Albert Meriwether, Lynchburg, Va.
Herman Paul Odessey, Washington, D. C.
Naum Levi Shamroy, New York City
Walter Schley Smith, Knoxville, Tenn.
Casper Lawrence Specht, Brooklyn, N. Y.
George Sylvester Vincent, Fort Worth, Tex.
Charles Curtis Woodruff, Jr., Forest Hills, N. Y.

The transfer of the following candidates on May 8th, 1922, was announced:

From Associate Member to Member

William Henry Adey, Cohoes, N. Y.
Sylvester Clay Baker, St. Louis, Ill.
Robert Burns Haldana Begg, Blacksburg, Va.
Harry Bennett, Mt. Vernon, N. Y.
Emmet Chadler Blosser, Columbus, Ohio
Clarence Edwin Boesch, Durham, N. C.
Charles Renwick Breck, Jr., New York City
George Valentine Clow, Dayton, Ohio
Orrin Fulton Cooley, Hollywood, Calif.
Henry Michael Dougherty, Chuquicamata, Chile
Robert Moore Dunham, Amarillo, Tex.
Frank Hoyt Fowler, Seattle, Wash.
Roger Deland French, Montreal, Que., Canada
Harry Parker Hammond, Brooklyn, N. Y.
Edgar Morton Hastings, Richmond, Va.
George Cleveland Haun, Chicago, Ill.
Roy William Hebard, New York City

John Spence Howard, Baltimore, Md.
Earle Kelly Knight, New York City
Clark Edwin Mickey, Lincoln, Nebr.
William Montgomery Mitchell, Detroit, Mich.
Howard Charles Paddock, Caldwell, N. J.
Charles Aloysius Petry, Urbana, Ill.
William Kerper Runyon, Lima, Peru
George Hudson Seybolt, Jersey City, N. J.
Benjamin Bruce Shaw, Little Rock, Ark.
James Elmo Smith, Urbana, Ill.
Walter Grover Smith, Newark, Ohio
Walter Lynes Smith, St. Louis, Mo.
Allen Whitmore Stephens, New York City
Edward Charles Stocker, Shanghai, China

From Affiliate to Member

Henry Rogers Codwise, Brooklyn, N. Y.

From Junior to Associate Member

Claude Gilbert Benham, Camp Bragg, N. C.
Earle Andrews Burt, Altadena, Calif.
Ham Kee Chin, Medford, Ore.
Victor Max Crown, La Paz, Bolivia
Donald Monroe Hatch, Wyandotte, Mich.
Charlie William Hickok, Ulysses, Kans.
Alexander Matthews McKean, Jr., Brooklyn, N. Y.
Thomas Francis McSweeney, Framingham, Mass.
Francis Harloe Phipps, Mt. Vernon, N. Y.
David Doak Rainey, Austin, Tex.
Norman Kirkwood Sheppard, Detroit, Mich.
Albert Victor Sielke, New York City
William Andrew Smith, Rifle, Colo.
Henry Case Willcox, New York City
Dee Leland Wilson, Miami, Fla.

From Junior to Affiliate

Jerome Brasil Francis Crowley, New York City

The following deaths were announced:

Ignacio Marea de Varona, of New York City, elected Member, April 7th, 1886; died May 12th, 1922.

Clement Alexander Finley Flagler, of Baltimore, Md., elected Member, March 13th, 1917; died May 7th, 1922.

David Henry Lane Kneedler, of Philadelphia, Pa., elected Member, March 9th, 1920; died February 20th, 1922.

The meeting was devoted to an informal discussion of the "Tentative Specifications for Steel Railway Bridges: Submitted as a Progress Report

of the Special Committee on Specifications for Bridge Design and Construction", which was opened by Henry B. Seaman, M. Am. Soc. C. E., Chairman of the Special Committee. The subject was discussed orally by Messrs. J. B. French, Benjamin W. Guppy, Charles Evan Fowler, D. B. Steinman, Otis E. Hovey, and Henry Goldmark, and written discussions were also received from Messrs. Theodore Belzner and Warrick R. Edwards.

At the request of President Freeman, a brief description of his trip around the world was presented by J. A. L. Waddell, M. Am. Soc. C. E.

Adjourned.

FIFTY-SECOND ANNUAL CONVENTION HELD AT THE HOTEL WENTWORTH, PORTSMOUTH, N. H. JUNE 21st—22d, 1922

FIRST SESSION

Wednesday, June 21st, 1922.—The Fifty-second Annual Convention was called to order at the Hotel Wentworth, Portsmouth, N. H., at 9: 30 A. M.; Arthur W. Dean, M. Am. Soc. C. E., Chairman of the Committee on Local Arrangements, presiding; Elbert M. Chandler, Acting Secretary; and present, also, about 125 members and guests.

THE CHAIRMAN.—Members and Guests of the American Society of Civil Engineers: As Chairman of the Local Committee on Arrangements, it becomes my duty, privilege, and pleasure to open this, the Fifty-second Annual Convention of the Society.

I want to say to those who have never been here before that this is one of the most beautiful spots on the New England coast. Nature has done a great deal for this territory, and, as you will see, man has also added much to the beauty of the spot. We had hoped to have the Convention at Bretton Woods, but the arrangements could not be made, consequently, Portsmouth was selected as being the next best place.

We had hoped to have with us Governor Brown, of New Hampshire, but he has telephoned that he had been delayed at the Dartmouth Commencement, and, consequently, could not possibly get here in time, and wished me to extend to you his personal greetings and welcome to New Hampshire. We have here, to give direct greetings and welcome, the Mayor of the City of Portsmouth. It gives me great pleasure, Ladies and Gentlemen, to present the Hon. F. W. Hartford, Mayor of Portsmouth. (Applause.)

MAYOR HARTFORD.—Mr. Chairman, Mr. President, Ladies and Gentlemen: The absence of Governor Brown from the gathering I much regret. In the early days, the Governor of New Hampshire resided in Portsmouth. This was the capital in the old Colonial days; out of this window you will see the Governor Wentworth Mansion, where the Governor and Council held their meetings.

There is so much that is historical hereabouts, so much dating back for more than 300 years, that I am not going to attempt to discuss it, because publications will be distributed to inform you of what can be seen and enjoyed

in searching the historic records and places of this community. I wish to tell you first that we feel that you have made no mistake in your selection of Portsmouth. It should have been your first choice instead of the second. Before you leave, we hope that those of you who have visited the mountains will be captivated with the grandeur of the scenery along this eighteen miles of sea coast, and that you will not only place us in the first rank, but that it will be your great desire to come here from year to year and enjoy all that we have, so rich and so beautiful.

The weather, I may say, at present is the worst we have had for many years. I am not going to say that we do not have rain in June, but I did feel that with the power and the skill that has been shown by the engineers of America, they would have been able, long ere this, to conquer the weather man and have the right kind of weather dealt out for these gatherings.

Engineers have done so much for the community and so much during the World War that there seems to be nothing that they are incapable of overcoming. You are going to have an opportunity to see the Memorial Bridge as it has progressed largely through the wonderful skill of engineering. It will be a monument in many ways: To the men who gave their lives in the World War, to the engineers who designed it, and to the men who made it possible to anchor these wonderful piers in this tide-water, which is, we acknowledge, not exceeded in strength in any river in the world. That has been accomplished through the skill of some of your members. This work has been conducted by a commission and a board of engineers that have given wonderful service, and it is going to be a credit to your Profession.

In this building, where your Convention is being held, the Russian and Japanese Delegates to the Peace Conference were located. The Russians were quartered in this half of the building and the Japanese in the other half, or *vice versa*. It was my pleasure at that time to be connected with the Associated Press, and I was in personal contact with all these men. I should like to tell you of some of the peculiarities of the Japanese and Russians during this time. They were like school boys. I happened to furnish the safe in which the Japanese kept their records. To show you their keenness, when the safe was sent down from Portsmouth, the first thing they wanted was the key. It was a combination safe, and I explained to them about the letters. "We want the key." "We want the key." They did not want any combination; they refused to turn it and used the inside doors with a lock. All through that Conference it was like boys' play between the Russians and the Japanese. I undertook to have a group photograph made before they came to terms, and we had a jolly time trying to bring them together. We finally got the group after the terms were settled and signed.

The way the news of that Conference was spread over the world may be of interest. I do not want to charge any intrigue or any secret service work, but during the Conference, whenever a pen touched the paper, the Associated Press had a man there, and click came the signal in my office in Portsmouth and it was flashed to all the world. When the late President Roosevelt sent his emissary here, which proceeding threatened to upset the whole plan, we captured the emissary at the Navy Yard gate and told him his mission.

President Roosevelt was obliged to admit later that such was the fact and that what we had stated was true.

A few thousand feet toward the river is the historic Walbach Tower and Fort William and Mary. From that spot the powder was taken to Durham, and from Durham to Bunker Hill, by Gen. John Sullivan, and history records that it was that action that saved America. I could go on into history about John Paul Jones, and Lafayette, and Washington, and their stay here, but you are going to have an opportunity, especially the ladies, I hope, during your visit, to go about with some of the Portsmouth guides and see all this for yourselves. At the Navy Yard, where the Peace Conference was actually held, the Peace Building is properly marked. In the interior, the place where each Commissioner sat is marked for your inspection, and so are many other things.

I am very glad that you have come here, and I hope your stay will be pleasant. If there is anything that Portsmouth can do in any way, we are yours to command. I thank you. (Applause.)

The Chairman.—Ladies and Gentlemen, we will now hear the response from President John R. Freeman. (Applause.)

The President.—I assure His Honor the Mayor how warmly we appreciate this hearty welcome that he has given us, and how glad we are to be here. I only wish that he might have talked longer and told us more of the wonderful history of this region.

This is not the Society's first Convention trip to New Hampshire. We have been here twice before, and I hope we will be here many times again. It is a wonderful State. In many ways the work that is done here is not appreciated—the great development of its water power, the remarkable products of its factories, and what it has done in many ways. Many of the rock drills and air compressors that are used in Colorado, in California, in Mexico, or in South Africa, are made here. The Sullivan Machine Company was named for this Governor Sullivan who has been spoken of by Mayor Hartford, and, in that way, his fame has been carried far beyond the limits of this State. The products of the factories of Manchester and many other New Hampshire cities and villages go all over the world. Cotton is brought from China to Nashua, and those of you who have shivered under cotton blankets in Colorado may reflect that probably they were made here in the State of New Hampshire. Cloth, shoes, buttons and paper made in New Hampshire go everywhere. I believe the largest button factory in the world is in this City of Portsmouth. In the pulp and paper industry there is no finer research laboratory anywhere in the world than that which is maintained at a New Hampshire paper mill at the edge of the White Mountains. Not only do they make substitutes for iron pipe out of paper, but their chemists are so ingenious that they have turned one of their by-products into chloroform, and by adding a molecule of hydrogen, they turn peanut oil into lard. I am sorry we have not time to see more of these wonderful industrial developments.

I am sorry, too, we have no opportunity in this morning's rain and fog to see the beauties of this particular spot. It is a beautiful spot. There is no more beautiful spot on the Atlantic Coast. For many years I have been along past here almost every summer, and there are several of us at this Convention

who from past experience know its delights. The weather that we are having to-day is not confined merely to New Hampshire. I had a telephone message from my office in Providence, R. I., a few moments ago, and they told me they were having the same weather there, and I am sure that the farther east you go the worse you will find it. So do not be too hard on the Local Committee who selected this spot. The fogs along this coast really are something wonderful. People from the West can hardly realize how thick and strong they are, particularly as one gets still farther east. There are stories farther down the coast, of a farmer who was shingling his barn. The fog was so thick that he could not find just where the edge of the barn roof was, and, after some time, he realized that he had been simply driving nails into the fog. (Laughter.) When we were tempted to hold to our printed program and make the trip to the Isle of Shoals this afternoon we did not dare to on account of this fog. We might land at the Azores or get outside the three-mile limit. (Laughter.)

The historical allusions by His Honor the Mayor certainly have been very interesting, and the members of the Society will be very glad to avail themselves of the kind invitation of the hospitable townspeople to see more of historic Portsmouth. (Applause.)

I will now proceed on the line of the formal address which the President is required to deliver at this time.

(President Freeman presented the Annual Address.*)

THE CHAIRMAN.—Ladies and Gentlemen, I have a few announcements to make.

(Several announcements relative to the Technical Meetings and excursions followed).

THE CHAIRMAN.—It has been a great pleasure to me as Chairman and to the members of this Local Committee to make, unmake, and make again arrangements for this Annual Convention. It has been rather uphill work in a great many respects, particularly during the last three days, when one could not help but worry as to whether or not the members present were having a good time, because the Committee could not give them the entertainment that it would like to on account of the unusual weather. One of the greatest pleasures, however, that comes to me as Chairman is that which I now take in resigning the chair to our worthy President, Mr. Freeman. (Applause.)

(President Freeman here took the chair and presided.)

THE PRESIDENT.—This meeting will be now resolved into a Business Session, which I think will be a short one.

I will ask the Acting Secretary if he has any report to make.

THE ACTING SECRETARY.—Mr. President, at the meeting of the Board of Direction on June 19th, 1922, the following elections and transfers were made:

AS MEMBERS

CHARLES EDWARD ANDREW, Olympia, Wash.
CHARLES ALLEN BROWNE, Orlando, Fla.
JOSEPH THEODORE CHASE, Roanoke Rapids, N. C.

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* See p. 1351 of Papers and Discussions.

Calvin Ira Crocker, New York City
Jacques de Tarnowsky, New Orleans, La.
William Adam Farish, Los Angeles, Calif.
William Morrow Francis, Wilmington, Del.
Carl Ewald Grunsky, Jr., San Francisco, Calif.
George Carl Halwas, Philadelphia, Pa.
Carroll Rede Harding, New York City
John George Heinz, Sunnyside, Wash.
Leslie Gilbert Holleran, Tuckahoe, N. Y.
Alfred Hughllyn Hunter, Peoria, Ill.
Charles Morris Hunter, Pounding Mill, Va.
Robert Fulton Jacobus, New York City
Fontaine Jones, Gastonia, N. C.
Charles Hunter Locher, Dayton, Ohio
Donald Smith McCalman, Cheyenne, Wyo.
Edgar William Maloney, Brooklyn, N. Y.
Harry Scott Marshall, Hamilton, Ohio
Roy Saxton Moore, Brooklyn, N. Y.
Caleb Norman Phillips, Dayton, Ohio
Arthur Joseph Mayer Proskauer, St. Louis, Mo.
William Herbert Rhodes, Baton Rouge, La.
Karl Augustus Sinclair, Portland, Ore.
Ralph William Stewart, Los Angeles, Calif.
Thomas Thomson Towles, Richmond, Va.
Fred Falconer Weld, Seattle, Wash.
Carroll Carson Wiley, Champaign, Ill.
William Felix Woodson, Richmond, Va.

As Associate Members

Earl Curtis Alexander, Chicago, Ill.
John Edwards Allen, Upper Darby, Pa.
Fred Harrison Austin, Webster City, Iowa
William Anthony Back, New York City
Albert John Bawden, Duluth, Minn.
Frederick Gardner Bennett, New York City
Gordon Roberts Bice, Utica, N. Y.
Charles Henry Buckius, New Castle, Pa.
Harry Poole Burden, Medford, Mass.
Seth Burnley, Charlottesville, Va.
Charles Claude Carroll, Charlottesville, Va.
Douglas Bryant Chapin, South Clinchfield, Va.
Shirley Thomas Corfield, Fresno, Calif.
Noah Cosores, Palisades Park, N. J.
William Harold Davis, Clarksburg, W. Va.
William Dee Dockery, Greenville, Tex.
Roderick Lyle Downing, Ogden, Utah
Joseph Andrew Dunn, Chicago, Ill.

Leo John Ehrhart, New York City
Parke De Camp Felch, New York City
Alexander Michael Fillot, Brooklyn, N. Y.
John Russell Fox, San Francisco, Calif.
Lloyd Ennis Gale, Hankow, China
John Stirling Gena, Dayton, Ohio
Mat Graham, Jr., Augusta, Kans.
Alexander Mason Harris, Richmond, Va.
Ralph Lemuel Hart, Chicago, Ill.
Charles Jefferson Hartenstine, New York City
George Willis Hutchinson, Raleigh, N. C.
George Norman Hyland, Philadelphia, Pa.
Eugene Keller, Jonesboro, Ark.
Charles Ainsworth Kendall, Wollaston, Mass.
Thomas Henry King, San Diego, Calif.
Frank Herbert Kinsey, Newark, N. J.
Jay Frank Krakauer, New York City
Ralph Louis Langenheim, Cincinnati, Ohio
Gustaf Harald Lundgren, London, England
Thomas George MacCarthy, Rolla, Mo.
William Kent McIlyar, Columbus, Ohio
Eric James Roland McLaren, Auckland, New Zealand
Walter Garnett Maddox, St. Louis, Mo.
John Lawrence Maher, Chillicothe, Ohio
Romeo Raoul Martel, Pasadena, Calif.
John Dickerson Martin, Pittsburgh, Pa.
Homer Mitchell Matthews, San Antonio, Tex.
Harry Edgar Miller, Raleigh, N. C.
Ray Dearborn Morgan, Temple, Tex.
George William Morton, Washington, D. C.
Philip Curtis Nash, Yellow Springs, Ohio
Archer Rice Norcross, Morgantown, W. Va.
Alfred Louis Ogle, Lincoln, Nebr.
Frank Andrew Ortman, Detroit, Mich.
Robert Leslie Pettigrew, Norfolk, Va.
Vincent Baldwin Phelan, New York City
Charles Albert Prokes, Hot Springs, Ark.
A. M. Rawn, King Hill, Idaho
Ernest Graham Rice, Portland, Ore.
Fred Gast Schworm, Philadelphia, Pa.
Sydney Hugh Smith, Mitchell, S. Dak.
William Mims Spann, Helena, Mont.
Angus Van Ausdol Swift, Albany, Ala.
Thomas Anderson Hendricks Teeter, Powell Butte, Ore.
Charles Mitchell Thomas, Seattle, Wash.
Royce Jay Tipton, Crestone, Colo.
Edward Kennedy Triol, Seattle, Wash.

Ralph Gilbert Wadsworth, San Francisco, Calif.
Harald Malcolm Westergaard, Urbana, Ill.
John King Woolf, New Orleans, La.
Alexander Woodward Yereance, South Orange, N. J.
Samuel Rollo Young, Atlanta, Ga.

As Affiliates

Perry Townsend Coons, Montclair, N. J.

As Juniors

George Lee Anderson, Memphis, Tenn.
Charles Henry Bartlett, New Haven, Conn.
Louis Henry Doane, Philadelphia, Pa.
Donald Ashworth Dudley, Chattanooga, Tenn.
Jacob Feld, Cincinnati, Ohio
John Laurens Guest, Charlotte, N. C.
Arthur Fox Holler, Port-of-Spain, Trinidad
Harry Louis Jacot, Jr., Binghamton, N. Y.
Yi Liu, Lansing, Mich.
Frank William Miller, Bethlehem, Pa.
John Anderson Miller, Jr., Newark, N. J.
Joseph Shipley Newell, Dayton, Ohio
Howard George Peterson, Dayton, Ohio
Fred Evans Portz, Arlington, N. J.
George Franklin Prong, Buffalo, N. Y.
John Walter Pumphrey, Park Hill, S. C.
Norman Cecil Raab, Sacramento, Calif.
Elliott Burgess Roberts, Washington, D. C.
Gur Bakhsh Singh, Ann Arbor, Mich.
Julius Slovenko, Cuyamel, Honduras
Joseph Murray Smook, Washington, D. C.
Sabro Uchimura, Urbana, Ill.
William Whetstone Wannamaker, Jr., Augusta, Ga.
Harlow Frank Wetherbee, Omaha, Nebr.
Jonathan Garrard Wright, Hayward, Calif.
Henry Why Yee, Kalamazoo, Mich.

From Associate Member to Member

George Crowell Andrews, Buffalo, N. Y.
Fred Asa Barnes, Ithaca, N. Y.
Robert Wright Boyd, New York City
Paul Bruce Breneman, State College, Pa.
Arthur William Bushell, Norwich, Conn.
Cloyde Cleaver Chambers, Dayton, Ohio
Sidney Kingman Clapp, Grand Gorge, N. Y.
Charles Bedard Dugan, Chicago, Ill.
William Patrick Feeley, Buffalo, N. Y.
Lawrence Machemer Fisher, Columbia, S. C.

HURLBUT SMITH JACOBY, Cleveland, Ohio
THOMAS MCLEAN JASPER, Urbana, Ill.
GEORGE KERR LITTLE, Oliver, Ky.
ARTHUR RUSSELL LORD, Chicago, Ill.
GEORGE ISRAEL OAKLEY, Little Falls, N. Y.
CHARLES SIESEL RINDSFOOS, New York City
GEORGE HERBERT SHAW, Philadelphia, Pa.
TYRRELL BRADBURY SHERTZER, New York City
ROY MARTIN SNELL, Browning, Mont.
ADALBERT GEORGE VOLCK, New York City
PAUL VOORHEES, Reading, Pa.
JAMES THOMPSON WARDLAW, Atlanta, Ga.
SIDNEY JAMES WILLIAMS, Chicago, Ill.

FROM JUNIOR TO ASSOCIATE MEMBER

EDWIN PRESCOTT BLY, San Francisco, Calif.
HORACE MORTON BRINGHURST, Cincinnati, Ohio
WILLIAM JOHN CAMLIN, Columbus, Ohio
GERALD MARCY KEITH, Brooklyn, N. Y.
HUNG HSUN LING, Peking, China
JOSEPH LOUIS LOIDA, St. Louis, Mo.
RAYMOND CASTLE REESE, Toledo, Ohio
EBERLE UPSHAW STEVENSON, Fort Worth, Tex.

I also wish to announce that the Board of Direction has elected as Secretary of the Society, John H. Dunlap, M. Am. Soc. C. E., and has also elected five Honorary Members, as follows: Clemens Herschel, Past-President, Am. Soc. C. E., and John F. Stevens, M. Am. Soc. C. E., both of the United States; Mr. W. C. Unwin, and Sir Maurice Fitzmaurice, of Great Britain; and M. Leon-Jean Chagnaud, of France.

The Board of Direction has also formally approved a new By-law providing for the formation of Technical Divisions within the Society, and there was definitely formed a Division of Sanitary Engineering. Action was also taken making possible the immediate formation of three other Divisions, one on Power, one on Irrigation Engineering, and one on Highway Engineering, on receipt of the proper petitions in the Secretary's office.

There are no further announcements, Mr. President.

THE PRESIDENT.—Is there any new business to be brought forward at this time? Has any member anything to introduce? There being no further business, the Business Meeting is adjourned and the members will proceed to the moving picture house, where the Technical Sessions will be held, as nearly all the papers to be presented at the meetings will be illustrated with lantern slides.

TECHNICAL SESSION

Wednesday, June 21st, 1922.—The first meeting of the Technical Session* was called to order at 10:30 A. M.; President John R. Freeman in the chair; Elbert M. Chandler, Acting Secretary; and present also 130 members and guests.

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* For papers and discussions presented at the Technical Sessions, see p. 1381 of Papers and Discussions.

A paper by W. K. Hatt, M. Am. Soc. C. E., entitled "Progress In and Importance of Highway Research", was presented by the author. Professor Hatt was followed by George C. Whipple, M. Am. Soc. C. E., who discussed the "Pollution of Streams by Paper Mill Wastes."

Mr. Harry W. Clark, Chief Chemist, Massachusetts State Board of Health, Boston, Mass., addressed the meeting on "Wastes from a Wood Pulp Mill Chemically Considered."

Adjourned to meet again at 2:30 P. M.

Wednesday, June 21st, 1922.—The meeting was called to order at 2.30 P. M.; President John R. Freeman in the chair; and present also 128 members and guests.

In continuance of the program provided for the Technical Session, a paper entitled, "Tests of Concrete in Sea Water,"* by L. C. Wason, M. Am. Soc. C. E., was presented by Mr. N. H. Mayo, in the absence of Mr. Wason.

This was followed by a paper on "Marine Borers" by W. G. Atwood, M. Am. Soc. C. E., which was discussed by Messrs. C. E. Grunsky and Robert A. Cummings.

A paper by Edward B. Wardle, M. Am. Soc. C. E., entitled, "The Wood Pulp Industry",* was presented by Mr. Wardle, and the subject was discussed by Messrs. Roscoe C. Young, Kenneth Allen, and W. G. Atwood.

Mr. O. Lefebvre, Chief Engineer of the Quebec Streams Commission, followed with a paper on "Problems in Connection with the St. Maurice River Regulations", and James H. Brace, M. Am. Soc. C. E., addressed the meeting on "The Gouin Dam on the St. Maurice River".

Adjourned to meet again at 8 P. M.

Wednesday, June 21st, 1922.—The meeting was called to order at 8 P. M.; President John R. Freeman in the chair; and present also 120 members and guests.

A paper by Frank W. Hodgdon, M. Am. Soc. C. E., entitled "Shore Protection and Harbor Development on the New England Coast", was presented by Mr. Hodgdon, and the subject was discussed by Messrs. Henry S. Adams, Frederic H. Fay and Lt.-Col. Wildurr Willing, Corps of Engineers, U. S. A.

This discussion was followed by a paper entitled "Difficult Foundation Problems for the Piscataqua Bridge at Portsmouth", by J. W. Rollins, M. Am. Soc. C. E.

Adjourned.

OF THE BOARD OF DIRECTION

(Abstract)

May 8th, 1922.—The Board convened in regular meeting at 8:10 P. M., at the Headquarters of the Society; Vice-President A. M. Hunt in the chair; Elbert M. Chandler, Acting Secretary; and present, also, Messrs. Greene, Hogan, Holland, Hudson, Humphrey, McConnell, Pegram and Ridgway.

Ballots for membership were canvassed, resulting in the election of 14

* These papers were not received in time for publication in this number of *Proceedings*, but will appear in a later number.

Members, 43 Associate Members, 4 Affiliates, and 9 Juniors, and the transfer of 15 Juniors to the grade of Associate Member, and 1 from Junior to Affiliate.

Thirty-one Associate Members were transferred to the grade of Member, and one Affiliate to the grade of Member.

A report from the Membership Committee was received and acted on.

Adjourned.

***June 19th, 1922.**—The Board met at 10 A. M., at the Hotel Wentworth, Portsmouth, N. H., at the time of the Annual Convention, as required by the Constitution; President John R. Freeman in the chair; Elbert M. Chandler, Acting Secretary; and present also Messrs. Anderson, Chester, Curtis, Darrow, Davis, Dyer, Grunsky, Henny, Hogan, Holland, Hoyt, Hudson, Humphrey, Hunt, McConnell, Marston (came in at 11:10 A. M.), Pegram, Ridgway, Talbot, Wall, Webster, Winsor, and Yates.

After discussion participated in by Messrs. Anderson, Davis, Hudson, Humphrey, and Yates, the minutes of the meetings of the Board held April 3d and 4th, 1922, on motion of Past-President Webster, duly seconded and carried, were approved with the following corrections, which were brought up by Director Humphrey:

The words, "New Pay," are to be eliminated† making the sentence read:

"Director Humphrey made a verbal progress report as the representative on the Joint Committee on Employment Bureau."

The sequence for holding the Annual Conventions of the Society is only to be regarded as fixing Conventions up to and including 1926, in which year the Convention is to be held in Philadelphia, Pa., at the time the International Engineering Congress is held there in connection with the Sesqui-Centennial.‡

The word, "tentatively," is to be eliminated,§ making the sentence read:

"Director Humphrey stated that the Philadelphia Section wishes to revise its Constitution, and asked whether the Board would approve such revision if it conforms to the standard."

The minutes of the meeting of the Board held May 8th, 1922, were approved.

The minutes of the meeting of the Executive Committee of February 14th, 1922, were approved at the meeting of the Board held April 3d, 1922, with the exception of the acceptance of the resignation of Charles Hayward Myers, M. Am. Soc. C. E., which was laid over until this meeting with the understanding that meanwhile the President would investigate the matter.

President Freeman reported in the matter and on motion of Vice-President Hunt, seconded by Director Anderson and carried, the resignation of Mr. Myers was accepted.

The minutes of the meeting of the Executive Committee of April 18th, 1922, were approved.

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* This is an abstract of the notes of the Acting Secretary and subject to approval by the Board of Direction at its next meeting.

† *Proceedings*, Am. Soc. C. E., May, 1922, p. 379.

‡ *Loc. cit.*, p. 386.

§ *Loc. cit.*, p. 390.

Messrs. Curtis and Humphrey discussed the matter of publishing the minutes of meetings of the Board in *Proceedings* before they had been approved by the Board, and on motion of Vice-President Hunt, duly seconded and carried, the Secretary was instructed hereafter to publish with the minutes a statement explaining that they are subject to review and final approval by the Board.

The President appointed Messrs. Davis and Talbot as Tellers to canvass the Membership Ballot. The Tellers subsequently reported and the President declared the election of candidates.*

Honorary Members Elected

The President appointed Messrs. Davis and Talbot as Tellers to canvass the ballots for Honorary Membership. The Tellers subsequently reported, and the President declared the election of the following Honorary Members:

Leon-Jean Chagnaud,
Sir Maurice Fitzmaurice,
Clemens Herschel,
John F. Stevens;
W. C. Unwin.

Report of Publication Committee *re* Advertisements

At the meeting of the Board of April 3d, 1922, the Publication Committee was requested to present to this meeting, a definite plan for soliciting and printing advertisements in *Proceedings,* setting forth the salient features in such a way that each might be separately acted upon. Discussion was to be limited to 5 min. for each member before voting.

President Freeman spoke and, on motion of Vice-President Hunt, duly seconded and carried, the matter was postponed until later in the session.

Chairman Davis, of the Committee on Special Committees, reported progress.

Committee on Licensing Engineers

Chairman Humphrey, of the Committee on Licensing Engineers, made a verbal progress report.

In this connection, the following letter from W. J. Wilgus, M. Am. Soc. C. E., dated May 26th, 1922, was presented:

"You will perhaps recall that over a year ago, to be exact, on April 15th, 1921, I addressed a letter to Colonel Crocker, then Acting Secretary of the Society, in which I made a suggestion that certain measures be taken to ascertain the sentiment of the membership of the Society on the bruited question of authorizing corporations to engage in the practice of our profession, directly or indirectly, through State licensing.

"As I understand it this question was referred to a Committee of the Board of Direction, but despite the passage of over a year I have not heard that the Committee has rendered a report or that the Board has taken any action on the matter.

"The enlightening series of articles on 'The Ethics of the Professions and of Business' that has appeared in the *Annals* of the American Academy of Political and Social Science, of which I sent you a copy, is clearly indicative of the fact that this is a live topic, and as one member of the Society I feel that we should be in the van rather than in the rearguard of an agitation which means so much for the professions of which we like to claim ourselves a part.

"May I, therefore, express to you the hope that we may soon hear from the Board on this subject."

* See p. 462.

The subject was discussed by Vice-President Hunt and on motion of Past-President Webster, duly seconded and carried, the letter was referred to the Committee on Licensing Engineers.

Reports of Various Committees of the Board

Messrs. Hudson and Humphrey, of the Committee to Consider the Whole Question of the Status of the Civil Engineer in Government Work and His Compensation, reported progress.

Chairman Humphrey, of the Committee to Report on Re-arrangement of the Fifteenth Floor, reported progress.

Chairman Wall, of the Committee on Collection of Funds for Bust of Capt. Eads, reported progress. ($2 418.02 is the net amount of subscriptions received to date.)

Vice-President Ridgway reported progress for the Alfred Noble Memorial Committee.

Benevolent Fund

Chairman Anderson, of the Committee to Investigate and Report in Regard to the Desirability of Creating a Benevolent Fund, called attention to the draft of the report submitted to the Board at its meeting of April 3d, 1922.

The subject was discussed by Director Humphrey and on motion of Vice-President Hunt, seconded by Director Humphrey and carried, it was decided that suggestions to this Committee should be indicated in writing rather than by discussion at this meeting.

Director Anderson asked for an expression of opinion in the matter from the Board, and on motion of Vice-President Hunt, duly seconded and carried, it was decided to be the sense of the Board that the adoption of something of this character was advisable.

Recess was taken for luncheon at 12:30 p. m.

The Board reconvened at 2:10 p. m., with the same attendance as in the forenoon.

Report of Publication Committee *re* Advertisements

Chairman Freeman of the Publication Committee reported progress in the matter of advertisements and Messrs. Chester, Humphrey, and Ridgway spoke.

On motion of Director Humphrey, seconded by Director Holland and carried, the Progress Report of the Committee was received, and additional time was granted to the Committee.

Student Chapters

Chairman Marston, of the Committee on Student Chapters, reported in favor of the formation of such Chapters at the University of Oklahoma and the North Carolina State College of Agriculture and Engineering, and on motion, duly seconded, these Chapters were approved, the latter, however, being contingent on the final approval by the Committee.

Chairman Talbot, of the Committee on Research, reported progress.

Report of Committee on Candidates for Secretary and Assistant Secretary

Chairman Freeman, of the Committee to Report on Candidates for Secretary and Assistant Secretary of the Society, explained that the Committee was

not then in position to make a final report. At its meeting of April 3d, 1922, the Board granted this Committee further time, and its report was to have been mailed to all Directors at least 20 days before this meeting.

Discussion was participated in by Messrs. Chester, Hogan, and Holland, and Director Humphrey suggested granting the Committee a recess of ½ hour, subject to the call of the President.

Executive Session

The Acting Secretary and his private secretary retired. Past-President Davis acted as Secretary.

Chairman Freeman, of the Committee on Nominations for Secretary, explained his efforts and inquiries concerning Messrs. Bass, Dunlap, Herrold, Gay, Paul, Provine, and Keller, stating that the Committee submits the names of the four leading candidates arranged alphabetically, without recommendation as to preference, namely, Messrs. Bass, Chandler, Conway, and Dunlap.

An informal ballot was first taken, with the following result:

Bass	0
Conway	2
Chandler	10
Dunlap	12

Director Humphrey moved that the Board ballot with the understanding that if election fails, a letter-ballot of the entire Board be taken. Director Marston seconded the motion.

Past-President Curtis moved to amend that the two letter-ballots from Directors Greene and O'Connor, be permitted to be counted.

Messrs. Grunsky, Hogan, Wall, Humphrey, Talbot, and Marston spoke.

Amendment lost, original motion carried.

First Formal Ballot:

Chandler	10
Dunlap	14

Director Humphrey moved for another ballot. Past-President Curtis spoke against. Director Chester seconded the motion, which was carried.

Second Formal Ballot:

Chandler	9
Dunlap	15

President Freeman announced the election of J. H. Dunlap, M. Am. Soc. C. E., as Secretary. Past-President Talbot moved his election be made unanimous. Motion failed.

Director Humphrey moved the salary of the Secretary be $10 000 per annum, which was carried.

Vice-President Hunt moved that the election of an Assistant Secretary be deferred until September. Carried.

Past-President Davis moved, seconded by Director Hudson, as follows:

"This Board, having full confidence in Mr. Elbert M. Chandler's integrity and high character, tenders its thanks and appreciation to him for his faithful and able services as Acting Secretary of this Society during a difficult period."

Carried unanimously.

Moved by Director Humphrey and seconded by Director Hogan that the notification of Mr. Dunlap of his election and the details of the assumption of his duties be left to the President with power.

Past-President Webster moved and Director McConnell seconded the

motion that the commencement of the salary of the Secretary be left with the President with power. Carried.

The Acting Secretary and his private secretary were recalled.

The Acting Secretary addressed the Board, stating:

"To the Members of the Board of Direction, I wish to express my appreciation of the opportunity to have served as the executive officer of this Society during the past thirteen months and to assure you of my co-operation to the full in assisting the new Secretary to get properly started." (Applause.)

Replies from Local Sections *re* Joining the Federated American Engineering Societies

The Acting Secretary presented the following report of actions taken by the various Local Sections on the question of the Society joining the Federated American Engineering Societies:

District.	Directors.	Local Section.	Sentiment.	Date of meeting.	Number present.	Vote.
1........	Greene....	New York........	Opposed..	Feb. 15, 1922	128	Almost unanimous.
	Hogan....					
	Holland...					
	Hudson...					
	McConnell					
	Yates.....					
2........	Winsor....	Northeastern	In favor*.	June 3. 1922	45	25 to 1
		Connecticut......	Opposed..	Mar. 25, "	24	15 to 7
		Providence.......	Opposed..	Mar. 28, "	11	11 to 0
3........	O'Connor.	Buffalo...........	Opposed..	Mar. 21, "	..	....
4........	Humphrey	Philadelphia	In favor†.	Mar. 6, "	..	Unanimous.
		Baltimore........				
		Lehigh Valley...				
5........	Hoyt	Dist. of Columbia	In favor..	Feb. 3, "	72	Unanimous.
		Atlanta...........	In favor..	June 12, "	16	10 to 4
		Virginia..........				
6........	Chester...	Pittsburgh........	In favor..	Feb. 24, "	Ballot	72 to 8
		Central Ohio.....	In favor..	....	..	....
		Cincinnati........	Opposed..	....	..	....
		Cleveland........	In favor†.	Mar. 27, 1922	Ballot	47 to 5
		Toledo............				
		Dayton...........	Opposed‡.	Apr. 17, "	18	Unanimous.
7........	Marston..	Iowa..............	In favor..	May 9, "	Ballot	39 to 7
		Northwestern....				
		Detroit...........	In favor..	....	..	....
		Duluth............	In favor§.	Feb. 20, 1922	21	Unanimous.
8........	Dyer......	Nashville.........	In favor..			
		Illinois—Think no commitment should be made without taking letter-ballot.		Mar. 24, "	30	23 to 7
9........	Brown....	St. Louis.........	In favor¶.	....	..	....
		Kansas City, Mo.	Opposed‖.	Mar. 7, 1922	9	Unanimous.
		Louisiana........	In favor..	Feb. 17, "	11	Unanimous.
10........	Darrow...	Nebraska.........				
		Colorado.........				
		Kansas...........	In favor..	Apr. 1, "	Ballot	21 to 11
		Utah..............	In favor..	May 9, "	Ballot	21 to 2
		Oklahoma........				
11........	Anderson.	Los Angeles......	In favor..	Feb. 8, "	38	Unanimous.
		San Diego........	In favor..	June 8, "	Ballot	9 to 1 (9 not voting).
		Texas............	In favor..	Apr. 4, "	Ballot	121 to 50
12........	Henny....	Portland, Ore....	Opposed..	Mar. 17, "	27	18 to 9
		Seattle...........	In favor**	Apr. 24, "	15	....
		Spokane..........				
13........	Huber....	San Francisco....	Opposed..	Feb. 20, "	86	36 to 22

* Of the 530 cards sent to the members in the Northeastern Section Territory, 48 were returned, of which 22 were in favor and 1 against, the others not voting.

† When finances permit.

‡ The Secretary of the Dayton Section has gathered the sentiment from the entire 45 members identified with the Section, which is opposed to the Society joining the F. A. E. S.

§ When finances permit. Ask for letter-ballot.

¶ It was the sense of the meeting of October 25th, 1920, that the Society should join the F. A. E. S. and reference is made to that action.

‖ It was the feeling of those present that they would not wish to commit the Section to any definite action on account of the small attendance, but the Secretary states the conclusion indicates what would probably be the majority vote of the Section.

** Request further letter-ballot when finances permit joining.

Director Hoyt reported that he had attended a meeting of the Baltimore Section which had unanimously voted in favor of joining the Federated American Engineering Societies, 25 members being present.

Vice-President Ridgway stated he had been informed that the sentiment of the Illinois Section was not correctly reported.

Director Humphrey moved:

"That it is the sense of this meeting of the Board that we join the Federated American Engineering Societies".

This motion was seconded and discussion was participated in by Messrs. Curtis, Davis, Hudson, Grunsky, Henny, Hogan, Hoyt, Humphrey, Hunt, Marston, and Talbot, during which Vice-President Hunt offered a substitute motion calling for a letter-ballot of the membership, which was subsequently withdrawn, and a motion by Past-President Curtis to lay Director Humphrey's motion on the table was lost by a show of hands resulting in 10 "ayes" and 13 "noes".

Director Marston offered the following as a substitute motion:

"That the question of joining the Federation be made the Order of Business at the next meeting and we invite the President and Secretary of the Engineering Council to meet with us to discuss it and that a report be rendered by the Executive Committee at the same time as to the prospect of discharging the obligation if favorable to joining".

This was seconded by Director Chester and carried by a show of hands resulting in 14 "ayes" and 8 "noes".

Joint Committee on Employment Bureau

Director Humphrey who represented this Society on the Joint Committee on Employment Bureau of the Federated American Engineering Societies, reported progress, stating that the following vote had been passed by the Executive Board of the American Engineering Council of the Federated American Engineering Societies discharging such Committee:

"*Voted:* That the Special Employment Committee be commended and thanked for the work and effort it had given to the report and that the Committee be discharged with an expression of appreciation for its services from the Executive Board".

Chairman Talbot, of the Committee on Honorary Membership, reported progress.

Director Holland, of the Committee on Federal Charter, reported progress.

The Acting Secretary made a verbal report on his visits to the various Local Sections in the New England District and vicinity.

Proposed Amendments to By-Laws

An amendment to Article I, Section 1, fourth paragraph, of the By-laws, was presented for final action, written notice of this amendment having been given at the April meeting of the Board and a copy forwarded each Director on May 4th, 1922. The proposed amendment will read as follows:

"Applications of Engineers not resident in Continental United States, and who may be so situated as not to be personally known to five Corporate Mem-

bers, may be recommended for ballot by five members of the Board of Direction, after having secured evidence sufficient, in their opinion, to show that the applicant is worthy of admission."

After discussion participated in by Messrs. Davis, Hogan, Humphrey, Hunt, Marston, Talbot, and Webster, on motion of Past-President Talbot, duly seconded and carried, the word, "and", was eliminated and the amendment was adopted as corrected.

An amendment to Article IV, Section 1, fourth paragraph, of the By-laws, was presented for final action, written notice of this amendment having been given at the April meeting of the Board, and a copy forwarded each Director on May 4th, 1922. The proposed amendment will read as follows:

"A Committee on Technical Activities and Publications."

On motion of Past-President Talbot, seconded by Director Humphrey and carried, this amendment was adopted.

An amendment to Article IV, Section 4, of the By-laws, was presented for final action, written notice of this amendment having been given at the April meeting of the Board and a copy forwarded each Director on May 4th, 1922. The proposed amendment will read as follows:

"The Committee on Technical Activities and Publications shall consist of five members, at least one being a member of the Board of Direction. It shall be charged with the promotion of the technical interests and the stimulation of the activities of the Society in technical professional matters. It shall have charge of the arrangements for technical and general meetings of the Society. It shall have general supervision of the publications of the Society and of the performance of contracts and expenditures connected therewith, and shall be authorized to make general rules for the preparation and presentation of papers. In addition to the regular membership of the Committee on Technical Activities and Publications advisory sub-committees may be appointed covering the principal branches of the Civil Engineering field, membership in which need not be confined to membership on the Board of Direction."

On motion of Past-President Talbot, seconded by Director Humphrey, and carried, this amendment was adopted with one dissenting vote.

An amendment to Article IV, Section 7, fifth paragraph of the By-laws, entitled "Funds," last sentence, was presented for final action, written notice of this amendment having been given at the April meeting of the Board and a copy forwarded each Director on May 4th, 1922. The proposed amendment will read as follows:

"All bills submitted by a special committee must bear the approval of its Chairman."

On motion of Past-President Talbot, duly seconded and carried, this amendment was adopted.

An addition to Article V, Section 7, Paragraph (*d*), of the By-laws, was presented for final action, written notice of this amendment having been given at the April meeting of the Board and a copy forwarded each Director, May 4th, 1922. The amendment will read as follows:

(*d*).—A membership card, of special design, prescribed in Section 9, to be issued annually; and the right to wear a badge of design prescribed by the Board of Direction;"

On motion of Past-President Talbot, duly seconded and carried, this amendment was adopted.

A proposed new By-law, to be known as "Article VII—Professional Divisions," was presented for final action, written notice of this amendment having been given at the April meeting of the Board, and a copy forwarded each Director on May 4th, 1922.

After discussion participated in by Messrs. Anderson, Chester, Davis, Humphrey, Hunt, Talbot, and Winsor, during which several amendments to the proposed draft were adopted, on Director Anderson's motion, seconded by Director Humphrey, the following was carried:

"ARTICLE VII—TECHNICAL DIVISIONS

"1.—A Technical Division of the American Society of Civil Engineers may, by the action of the Board of Direction, be organized for the consideration of any engineering, scientific, or professional subject, provided that not less than 20 members of the Society unite in making written request for such an organization. Such a division shall be designated as.......... Division of the American Society of Civil Engineers. (The blank shall be filled by the title of the subject specialized.)

"2.—Members of the Society of any grade may be members of the Division by enrollment.

"Engineers and others not members of the American Society of Civil Engineers, desiring to participate in the meetings may be enrolled as Division Members upon approval of the Executive Committee of the Division. Such Division Members shall not be in any sense members of the American Society of Civil Engineers in any grade, but shall have the privilege of attending meetings, presenting papers, and taking part in the discussion, but shall have the right of voting only on technical matters.

"A Technical Division may levy additional dues upon its enrolled members by action of the majority of the Division Members, subject to the approval of the Board of Direction of the Society.

"3.—The Division shall elect annually an Executive Committee of 5 members of the Division who shall be Corporate Members of the American Society of Civil Engineers, to have charge of its affairs under the guidance of the Board.

"Other Committees of the Division shall be appointed by its Executive Committee.

"4.—The Division shall incur no financial obligations chargeable to the Society unless such are specifically authorized by the Board of Direction and provided for in its approved budget. No liability incurred other than as above provided shall be binding on the Society.

"5.—The Board of Direction of the Society may suspend or disband any Division, on 60 days' notice."

After further discussion participated in by Messrs. Chester, Davis, Humphrey, Hunt, Marston, Talbot, Wall, and Webster, the following motion of Vice-President Hunt, which was seconded by Past-President Talbot, was carried unanimously:

"That the vote as taken on the proposed By-law be warrant and justification for the officers of the Society for proceeding in accordance with it, and that at the next meeting of the Board, it be brought up for confirmation and approval."

Recess was taken for dinner at 6:35 P. M.

The Board reconvened at 8:15 P. M., with the same attendance as in the afternoon, except that Messrs. Hogan and Holland were absent.

PROPRIETY OF ISSUANCE OF LITERATURE CONCERNING BALLOTS AND CANDIDATES FOR OFFICE

Director Chester referred to the matter of the sponsors of George S. Davison, M. Am. Soc. C. E., for Vice-President in Zone 2 having sent extra ballots to the membership therein and questioned the validity of such ballots, stating that a pamphlet concerning the candidate was also sent.

Discussion was participated in by Messrs. Anderson, Chester, Davis, Grunsky, Henny, Hudson, Humphrey, McConnell, Marston, Ridgway, Talbot, and Wall.

The Acting Secretary inquired as to the desirability of Society Ballots being printed on special water-marked paper, in an effort to prevent the printing of ballots similar to those issued by the Society, and reported that the printer had been instructed not to duplicate ballots printed by the Society, unless the order was received from the Society.

On motion of Director Anderson, seconded by Director Winsor, the following resolution was carried:

"That a ballot, whether it is on the actual form furnished by the Society, as long as it is for the office to be voted upon and signed by a member in good standing, should be received as a legal ballot. It does not matter whether written, typewritten or not".

On motion of Director Henny, duly seconded and carried, the following resolution was adopted:

"That the Secretary be instructed to furnish extra ballots to Secretaries of Sections that ask, limited to 25% of the membership of the Section."

Director Chester suggested that the following be adopted:

"It is the sense of this Board that the activities of the Committee in support of Mr. Davison have not as yet done anything unethical."

Vice-President Hunt seconded the motion.

Vice-President Ridgway moved that the whole matter be laid on the table. This motion was seconded, but was lost by show of hands resulting in 8 "ayes" and 9 "noes".

Director McConnell offered as a substitute motion:

"That the Secretary be instructed to write the Committee, and the people involved in this transaction, that the growth of propaganda is regarded by the Board of Direction as reprehensible, and that they be requested to refrain from it and to use their influence in the future to keep it down within the Society."

Director McConnell re-stated his motion as follows:

"That the Secretary be instructed to write to the Candidate, and the Committee, that there is a tendency for propaganda of this character to grow in the Society; that the Board of Direction regards that sort of propaganda as detrimental to the best interests of the Society, and requests them to desist from further efforts and to use their efforts to discourage such further efforts."

Director Chester suggested that a copy of the foregoing action be sent to the Secretary of the Committee on the "other side", Mr. Schein, and stated that such copy would not be published and he would agree that it would not be used as propaganda.

Vice-President Hunt suggested that the letter written by the Secretary in the matter should meet with the approval of the President.

Director Marston moved that Director McConnell's motion be laid on the table, which was seconded by Director Henny, and carried.

The Board adjourned at 10:50 P. M., June 19th, 1922, to meet at 9 A. M., June 20th, 1922.

June 20th, 1922.—The Board reconvened at 9:15 A. M., at the Hotel Wentworth, Portsmouth, N. H.; President John R. Freeman in the chair; Elbert M. Chandler, Acting Secretary; and present also Messrs. Anderson, Chester, Curtis, Darrow, Davis, Dyer, Grunsky, Henny, Hoyt, Hudson, Humphrey, Hunt, McConnell, Marston, Pegram, Ridgway, Talbot, Wall, Webster, Winsor, and Yates.

Suggested Technical Divisions

The Acting Secretary reported that, under date of February 8th, 1922, Director Hogan had forwarded to President Freeman a letter which he had received from Irving Weed, M. Am. Soc. C. E., asking why the Society cannot have a Power Section, and that Director Hogan endorses the letter and considers that a Power Section would be a most active and interesting Section and would be well supported by the membership. (The Committee on Technical Activities and Publications has authorized and appointed an Advisory Sub-Committee on Power.)

On motion of Director Humphrey, duly seconded and carried, a Technical Division on Power was authorized.

It was reported that a petition, signed by 33 members, has been received for the formation of a Sanitary Engineering Technical Division.

On motion of Director Humphrey, duly seconded and carried, a Sanitary Engineering Technical Division was authorized.

It was reported that Director Henny had written in favor of the formation of an Irrigation Engineering Technical Division, which might have its first meeting in San Francisco, Calif., at the time of the 1922 Fall Meeting of the Society.

On motion of Director Humphrey, seconded by Director Henny and carried, an Irrigation Engineering Technical Division was authorized when the necessary signatures are received.

Director Marston offered a motion which was seconded and carried, authorizing the formation of a Highway Technical Division when the necessary signatures are received.

In connection with the letter written to the Board, dated May 5th, 1922, citing the overlapping and duplication in the existence of sixteen Civil Engineering organizations, the Acting Secretary suggested the appointment of a committee to urge the various existing engineering organizations to become

Technical Divisions of the Society, and Director Humphrey made such motion which was seconded by Director Winsor.

After discussion participated in by Messrs. Anderson, Davis, Dyer, Humphrey, Talbot, and Yates, including the offer of various amendments, the proposed motion was finally adopted in the following form:

"That the President appoint a Committee of five, one to be the Secretary, and the others to be members of the Board, to bring to the attention of any Civil Engineering organizations within its discretion, the advantages of becoming a Technical Division of the Society, and actually to promote the consummation of such changes, and to consider the question of co-operation with other engineering organizations."

The Acting Secretary further suggested a study of Engineering Society Organization, and presented the following for adoption:

"*Whereas,* There are a very large number of National engineering societies and many other technical societies, closely related, in addition to local sections of a number of these societies and numerous regional, State, and local societies; and

"*Whereas,* There is confusion and duplication of activities among these organizations and increased cost for meetings, publication, and administration; and

"*Whereas,* There is no comprehensive information available as to existing organizations and their purposes, relations, and plans, or as to needs which are not being satisfied; now, therefore, be it

"*Resolved:* That it is the opinion of the Board of Direction of the American Society of Civil Engineers that the Profession can be benefited through economy of effort and funds by simplification of the present confused state of its organizations; and

"*Resolved:* That, in the opinion of the Board, most effective progress can be made toward this desired end by ascertaining the facts as to present conditions and as to the needs to be met; and since this is a subject for study by competent, carefully selected investigators under an impartial body representing the whole Profession; be it further

"*Resolved:* That Engineering Foundation be requested to make the proposed study and to publish a report, to which end the American Society of Civil Engineers pledges support and refers to its Executive Committee the preparation of a financial plan with power. Also, that the other three Founder Societies be invited to join with the American Society of Civil Engineers in requesting Engineering Foundation to undertake this work."

Director Winsor moved the adoption of this resolution, which was seconded by Vice-President Grunsky, and carried.

Reports from the Acting Secretary on Various Activities

The following matters were reported for the information of the Board:

Canvass of "First Ballot" for Nominees for Officers:

As authorized by the Board at its meeting of April 3d, 1922, President Freeman appointed the necessary Tellers (James F. Sanborn, M. Am. Soc. C. E., *Chairman*) to make this canvass, which was done on June 1st, 1922, and on June 15th, the result of said "First Ballot" was issued to the Corporate Membership, with request for a "Second Ballot".

Committee on Professional Conduct:

At the meeting of the Board on April 3d, 1922, President Freeman was authorized to appoint such Committee and it was reported that he had appointed Messrs. George H. Pegram, *Chairman,* A. M. Hunt, and I. W. McConnell.

Special Committee on Bridge Design and Construction:

At the meeting of the Board held April 3d, 1922, President Freeman was authorized to appoint not more than five additional members on the Special Committee on Bridge Design and Construction, on the recommendation of the Committee on Special Committees, and it was reported that the following new members had been appointed: John H. Ames, E. F. Kelley, and S. B. Slack.

Resignations on this Committee have been received from Messrs. J. R. Worcester and B. R. Leffler, and President Freeman has appointed Messrs. J. E. Greiner and I. F. Stern to take their places, who have accepted. Howard C. Baird, M. Am. Soc. C. E., has also resigned as a member of the Committee, and President Freeman has appointed C. R. Harding, M. Am. Soc. C. E., to fill the vacancy.

Joint Committee on Concrete and Reinforced Concrete:

At the meeting of the Board on April 3d, 1922, it was reported that President Freeman had under advisement, the matter of filling the vacancy caused by the resignation of W. K. Hatt, M. Am. Soc. C. E., as one of the representatives of this Society on the Joint Committee on Concrete and Reinforced Concrete. It was reported that Milton H. Freeman, M. Am. Soc. C. E., had been appointed to fill this vacancy, and had accepted.

Committee on Prizes:

At the meeting of the Board on April 3d, 1922, the President was authorized to appoint a Committee on Prizes for 1922. It was reported that Messrs. Leonard Metcalf, George W. Kittredge, and G. R. Putnam had been appointed as such Committee, and that all the appointees had accepted, except Mr. Metcalf, who had declined. Thomas H. Wiggin, M. Am. Soc. C. E., has been appointed in his place, and has accepted.

Society Invited to be Represented on Advisory Committee of Scientists to Pass on Official Water Standards:

At the meeting of the Board on April 3d, 1922, the President was authorized to designate such representative. It was reported that George C. Whipple, M. Am. Soc. C. E., had been appointed and had accepted.

Standardization in the Lumber Industry:

In a letter dated May 9th, 1922, the American Engineering Standards Committee invited the Society to send representatives to a meeting in Washington, D. C., on May 24th, 1922, to consider lumber sizes and other questions of standardization in the lumber industry. It was explained that the proposed series of meetings is the outcome of the suggestion of the National Lumber Manufacturers Association, and that the Department of Commerce had asked the Committee to extend invitations to technical bodies. It was reported that President Freeman had appointed Messrs. R. E. Dougherty and T. W. Norcross as such representatives from the Society. The former was unable to attend the meeting, but Mr. Norcross had attended and had forwarded a report for the record.

International Engineering Congress in Philadelphia, Pa., in 1926:

At the meeting of the Board on April 3d, 1922, the invitation to be one of the sponsors for this Congress was accepted, and it was also decided that

the President and Secretary and four other members, to be appointed by the President, were to be delegates to represent this Society at the conference to formulate a general plan for this Congress, which conference is to be called by the Philadelphia Engineers Club. It was reported that Messrs. George S. Webster, Richard L. Humphrey, John S. Conway, and J. P. H. Perry, with the President and Secretary, are the Society's delegates.

(The Secretaries of the Founder Societies have conferred in an endeavor to amalgamate the various conflicting views into one comprehensive whole mutually satisfactory to all interests, and have outlined a plan of organization which they have submitted to their respective Presidents. This coincided with the action of this Society, and seemed to be necessary in order to get the other three Societies to come together with this Society and the Engineers' Club of Philadelphia, and the organization meeting can have the outline as a basis for its consideration. The Presidents have conferred and considered the plan of the Secretaries, and with some modifications of minor importance, have approved the same; have notified the Engineers' Club of Philadelphia of the plan proposed; and the condition now is that all organizations are waiting for the President of this Society to call the proposed conference in Philadelphia.)

University of Southern California:

An invitation to be represented at the ceremonies attending the inauguration of Rufus Bernhard von Kleinsmid as President of the University of Southern California, on April 27th-29th, 1922, was received on April 20th, and President Freeman appointed Director Anderson to represent the Society on that occasion. Mr. Anderson was called out of town and asked that Ralph J. Reed, M. Am. Soc. C. E., be appointed, which was done. Mr. Reed attended the ceremonies and has forwarded copy of the program for the record.

Appointment of Committees:

The President still has under consideration the appointment of the following committees: on Stresses in Structural Steel; on Impact in Highway Bridges; on Hydraulics Phenomena; on Irrigation Hydraulics; and on Flood Protection Data.

Pollution of Water by Industries

The Board, at its meeting of April 3d, 1922, adopted a resolution regarding the Pollution of Waters by Industries, which was forwarded to various interested persons, including the President of the United States, the Secretary of War, the Secretary of Commerce, the Chairman of the Committees on Commerce of the U. S. Senate and House of Representatives, as well as to the President of the Senate and Speaker of the House, and to the Chief of Engineers, U. S. A.

It was reported that the reply received from the Secretary of War states that Congress acted in this matter in 1912 and annual appropriations have been made. It was also reported that Charles Haydock, Assoc. M. Am. Soc. C. E., who first brought the matter to the attention of the Board, was notified of the reply received from the Secretary of War, but Mr. Haydock feels there is no overlap in the investigation recommended by this Society and that already done by the Public Health Service.

No action.

Campaign to Increase Membership

In accordance with the action of the Board at its April meeting, communications were forwarded to the President and Secretary of each Local

Section in an effort to initiate a campaign to increase the membership of the Society along the lines suggested by President Freeman, and replies from the following Sections have been received:

Cleveland Section:

"Referring to your communication of action of the Board with reference to securing new members, I wish to advise that the Cleveland Section has appointed a committee to report to the Section the names of desirable candidates in this vicinity.

"At the last meeting of the Section, President Ruggles presiding, twelve corporate members present, it was voted to be the sense of the Section that the solicitation of members at the present time would be unwise and inconsistent, in view of the continued unsettled condition of the internal affairs of the Society.

"For the past several years, the Society has been a 'house divided against itself.' That this state of affairs is not yet settled is evidenced by the fact that the Board is still unable to elect a Secretary.

"It is the judgment of the Cleveland Section that the Society should settle its internal affairs and place them on a stable basis before going to the public for an increase in membership."

Dayton Section:

"Replying to your circular letter of April 29th, regarding the campaign for new members, you may have noticed that the Dayton Section started a canvass of this neighborhood some time ago. You already have 15 or 20 applications from good men in this vicinity, who should have become members before this time."

Duluth Section:

"Yours of the 29th ult., quoting letter from President Freeman in reference to proposed dignified campaign for increased membership is at hand, and the matter will be presented at our next meeting in the usual way. In the meantime, please note that we have always been more or less active along the line of increased membership in the Society and our Section, and have recently had some correspondence with you in reference to certain applications which are now in your hands for action by the Board. * * *"

Los Angeles Section:

"* * * This suggestion of President Freeman has been in force in the Local Section for some time past, and we have made it a point to look up the credentials of prospective members and, in a dignified way, invite them to become members of the American Society of Civil Engineers, as will be borne out by some of the recent names added to the local membership of the Society. You may count on our hearty co-operation in this matter."

Toledo Section:

"* * * I shall take this up here with our Local Secretary and give it very careful thought and we will do what we can along the lines suggested. You may be sure that we will be careful and conservative with the thought of maintaining the present high standard of the Society membership."

Virginia Section:

"* * * At the meeting, we discussed the matter of encouraging qualified engineers to join the Society, as requested in your recent letter, and it was agreed that we can greatly increase the membership of the Society. Representatives will be appointed in the various centers throughout the State to carry out this plan in accordance with the suggestions of President Freeman."

Proposed American Construction Council

It was reported that, in accordance with action of the Executive Committee, President Freeman had appointed Messrs. John S. Conway and G. B. Strickler as delegates to attend the organization meeting of the American Construction Council in Washington, D. C., on June 19th and 20th, 1922, with a view to ascertaining the purposes of the Council and whether or not the Society should participate, and that they had accepted such appointment and will doubtless report to the Board later.

Director Humphrey moved the approval of the action of the Executive Committee, which motion was duly seconded and carried.

Invitation to Appoint Representative on Sectional Committee on Safety Code for Mechanical Refrigeration

A letter was presented from Dr. A. S. McAllister, of the American Engineering Standards Committee, dated May 18th, 1922, inviting this Society to appoint a representative on the Sectional Committee on the Safety Code for Mechanical Refrigeration.

On motion of Director Humphrey, duly seconded and carried, this matter was referred to the Committee on Special Committees with request to make a recommendation to the Executive Committee for action.

Standardization of Methods of Testing Wood

A letter was presented from C. L. Warwick, Assoc. M. Am. Soc. C. E., Secretary-Treasurer of the American Society for Testing Materials, and Earle H. Clapp, Assistant Forester, U. S. Forest Service, dated April 3d, 1922, inviting this Society to appoint a member to serve on a representative Sectional Committee to be formed by the American Society for Testing Materials and the United States Forest Service which have been designated by the American Engineering Standards Committee as Joint Sponsors for the Standardization of Methods of Testing Wood.

On motion of Director Humphrey, seconded by Director Marston and carried, the President was authorized to appoint such representative.

Cable Code Especially Adapted to Engineering

A letter was presented from W. J. Wilgus, M. Am. Soc. C. E., dated June 15th, 1922, suggesting that the Society investigate the wisdom of evolving a universal cable code especially adapted to engineering.

On motion of Director Humphrey, seconded by Past-President Curtis and carried, this matter was referred to the Committee on Special Committees for consideration and report.

The Panama Canal

A letter was presented from the American Engineering Standards Committee, dated May 19th, 1922, stating that the Committee has voted in favor of the admission of The Panama Canal to its membership and recommends that the member bodies act favorably thereon.

On motion of Director Yates, seconded by Director Humphrey, and carried, favorable action was taken on the letter.

Employment Bureau

It was reported that the Federated American Engineering Societies has decided to discontinue the conduct of the Employment Bureau, commencing with July 1st, 1922, and expects the four Founder Societies to conduct it in the future. It has been managed, under the auspices of the Federated American Engineering Societies, by a Temporary Committee composed of the four Secretaries. Prior to the Employment Bureau being taken over by the Federation, it was managed solely by this Committee.

It was suggested that the following resolution be approved:

"*Resolved:* That the Secretary be directed to continue the Employment Service practically as rendered for several years past to the membership of this Society, and that he be authorized to co-ordinate this service with the employment activities of the other Engineering Societies."

Director Humphrey stated he would make the above motion, which was duly seconded and carried.

After discussion concerning the whole matter had been participated in by Messrs. Chester, Curtis, Hudson, Humphrey, and Webster, Past-President Davis further moved:

"That the Executive Committee be requested to investigate and report upon the feasibility of having clearing houses or registration bureaus established by each, or some at least, of the Local Sections of the Society, to act in co-operation with the central committee and to report the cost of that kind of service."

This motion was carried with the following amendment offered by Vice-President Hunt:

"To include any further recommendations in connection with employment service which seem proper."

Director Humphrey further suggested:

"That the Executive Committee consider also the desirability or undesirability of making a charge to those who make applications for position to the service".

Marine Piling Investigations

A letter was presented from Chairman Flinn, of the Division of Engineering of the National Research Council, dated May 19th, 1922, addressed to President Freeman, regarding marine piling investigations, and requesting an appropriation from the Society of $1 000, or such other sum, larger or smaller, as may seem appropriate to the Board of Direction or the Executive Committee.

Discussion was participated in by Messrs. Grunsky, Humphrey, Marston, Ridgway, and Yates.

On motion of Director Humphrey, seconded by Director Henny, and carried, the question of representation on this investigation was referred to the Committee on Special Committees and the question of appropriation was laid on the table.

Additional Appropriation for Special Committee on Bridge Design and Construction

A letter was presented from Chairman Seaman, of the Special Committee on Bridge Design and Construction, dated June 15th, 1922, requesting additional appropriation of $1 000.

On motion, duly seconded and carried, this was referred to the Executive Committee with power.

Local Sections

A letter, dated May 10th, 1922, from the Toledo Section was presented, asking whether "it is possible for the Society to advance the per capita allowance made to each Local Section at this time; this, of course, to cover only those cases where dues have been paid by Members belonging to this Section? A portion of the full amount would be appreciated."

It was explained that the Toledo Section was approved January 17th, 1922. The allotment of $1.00 per member to Sections has been made per the ruling of the Board in accordance with membership of a Section as of January 1st, 1922. Therefore, allotments have not been made to Sections approved after the first of this year.

On motion of Director Humphrey, duly seconded and carried, this matter was referred to the Executive Committee with power and with the favorable recommendation of the Board.

A letter from the Virginia Section was presented, dated May 13th, 1922, asking the Board to allow the Section the same amount allotted to the other Sections of the Society.

It was explained that the Virginia Section was not approved until April 4th, 1922, and it has been ruled that allotments to Local Sections would be on the basis of members in good standing, both in the Section and the Society, as of January 1st, 1922, and that the dues of the Section should amount to at least $1.00 per year.

The following motion was made by Director Humphrey, seconded by Director Hudson, and carried:

"That the matter be referred to the Executive Committee with power and with recommendation for favorable action, of course, it being understood that the previous action of the Board in regard to charging dues is adhered to before appropriation is made."

It was reported that a letter of April 24th, 1922, from the Philadelphia Section gave the result of the letter-ballot on the Revised Constitution of the Section as 78 in favor and 3 opposed; that the Revised Constitution is in correct form for approval by this Board, except that it apparently has not been voted on by more than a majority of the membership of the Philadelphia Section, because $208 was refunded to the Section, which would mean that more than 104 members would have to vote on passing the Revised Constitution and that two-thirds would have to be favorable for its adoption. Director Humphrey reported to the Board at its April meeting that this revision was contemplated and he asked, and the Board did, approve such revision, providing that when it was received, it conformed to the standard.

Director Humphrey reported that the Section now has a ballot out, and he was sure that the necessary majority would be received and no further action would be necessary.

Research Council

It was reported that the term of Director Anson Marston as one of the representatives of the Society on the Engineering Division of the National Research Council will expire on June 30th, 1922, and that under the rules of the Council, he is not eligible for re-election at the present time.

On motion of Director Humphrey, duly seconded and carried, the Executive Committee was empowered to fill this vacancy.

Committee on Districts and Zones

The Constitution provides that the Board of Direction shall review annually the existing divisions and announce the District boundaries, the number of Directors for each District, and the boundaries of the four Zones, as provided in Article VII of the Constitution, to the Corporate Membership not later than April 1st. Protests* have been received from the Colorado and San Francisco Sections concerning the existing District boundaries, and a letter was presented from W. H. Breithaupt, M. Am. Soc. C. E., dated June 15th, 1922, suggesting that the Board consider the possibility of making the whole of Canada a separate voting District.

On motion of Director Humphrey, duly seconded and carried, the Executive Committee was empowered to appoint a Committee on Districts and Zones to report to the Board at its January, 1923, meeting, and these communications are to be referred to that Committee.

Consolidation of Monthly Society Meeting with That of New York Section

President Freeman suggested the possibility of consolidating the monthly Society Meeting with that of the New York Section, and the matter was discussed by Messrs. Davis, Hudson, Humphrey, Ridgway, and Yates.

Director Humphrey offered the following amendment to the By-laws: Amend Article VI, Section 1, of the By-laws, by striking out the first sentence and amending the second sentence to read as follows:

"In addition to the Annual Meeting and the Annual Convention, meetings for the transaction of business and for the reading and discussion of papers shall be held as ordered by the Board of Direction."

This is to be regarded as the requisite written notice to the Board of this proposed amendment to the By-laws, and the matter will come up for final action at the meeting of the Board in San Francisco, Calif., in October, 1922.

Publication for Student Chapters

The Acting Secretary reported that the number of Student Chapters has grown from 7 to 51 in little more than a year, comprising 3 100 members, which fact brings out the necessity for some consideration of co-ordinating their actions and stimulating their activities. It has been suggested that

* *Proceedings*, Am Soc. C. E., May, 1922, p. 384.

this might be accomplished by the publication once a year of the *Proceedings* of Student Chapters, which might contain portraits of the Presidents of the Chapters, a statement from each Chapter of its activities for the year, the number of members in attendance at meetings, speakers, total number of members, and other matters of interest; also a brief introductory statement written in somewhat popular style, telling how one live Chapter succeeded. It is probable that an edition of 6 000 would enable all members of Student Chapters to be supplied, and if this pamphlet is printed in the same type as that used for the *Proceedings* of the Society, the cost would be about $1 000.

This matter was discussed by Messrs. Freeman, Humphrey, Hunt, and Marston.

On motion of Director Humphrey, duly seconded and carried, the matter was referred to the Committee on Student Chapters for recommendation, and its recommendation is to be referred to the Publication Committee for report to the Board.

The Board recessed at 11:50 A. M., to meet at 2 P. M., as a Membership Committee.

The Board reconvened at 5:55 P. M., at the conclusion of the meeting of the Membership Committee, with the same attendance except that Messrs. Hudson, Hunt, and Talbot were absent.

The report of the Membership Committee was presented.

On motion, duly seconded and carried, the recommendations of this report, which was not read, were adopted as the action of the Board.

Constitution of Nashville Section

It was reported that the following amendment to the Constitution of the Nashville Section was adopted at a meeting of that Section held May 27th, 1922:

"Proposed amendments to the Constitution shall be reduced to writing and signed by at least three members. They shall be presented and discussed at the next membership meeting and affirmative vote of two-thirds of all ballots cast shall be necessary for adoption of any Amendment. No vote on a proposed Amendment shall be taken unless there are present and voting, either in person or by proxy, at least a majority of the total membership of the Section. No Amendment can be finally adopted until it has received the approval of the Board of Direction of the American Society of Civil Engineers."

This amendment was adopted in order to comply with the rules of the Board of Direction, and is in correct form.

On motion of Director Humphrey, seconded by Director Marston and carried, this amendment was approved.

On motion of Director Humphrey, the Board adjourned at 6:20 P. M., to meet at 8 P. M., August 28th, 1922, at the Headquarters of the Society.

EXCURSIONS AND ENTERTAINMENTS AT THE FIFTY-SECOND ANNUAL CONVENTION

The arrangements for the Convention were in the hands of the following Local Committee:

A. W. Dean, *Chairman,*

F. A. Barbour,	F. C. Shepherd,
F. E. Everett,	C. W. Sherman,
F. W. Hodgdon,	C. M. Spofford,
E. H. Rogers,	W. C. Voss,

B. T. Wheeler.

Automobile Trips around Boston, Mass.

On Monday and Tuesday, June 19th and 20th, and on Friday and Saturday, June 23d and 24th, 1922, the Committee arranged to entertain the visiting members and guests who might arrive in Boston for a visit preceding or following the Convention. This entertainment consisted in automobile sightseeing trips around the city, and visits to various engineering works in the vicinity and to various points of historical interest. Through the courtesy of the Boston Society of Civil Engineers, the Club Rooms of that Society were available as a meeting place and a starting point for the excursions. About 70 members and guests took advantage of this opportunity.

Trip to Worcester and Clinton, Mass.

Tuesday, June 20th.—Members and guests to the number of 35 went on the inspection trip to Worcester and Clinton. The party left Boston by automobile, or were met at Worcester, where they inspected the Sewage Disposal Plant. After this visit, the party proceeded by automobile to Clinton, where the Wachusett Reservoir which constitutes the main water supply for the City of Boston, is located. After the inspection of these projects, a basket lunch was served, after which some members motored to Portsmouth, N. H., to attend the Annual Convention, the remainder returning to Boston.

During the afternoon such members and guests as had already arrived at the Convention Headquarters at Portsmouth, were entertained with an automobile sightseeing trip around that city.

Automobile Trip around Portsmouth

Wednesday, June 21st.—During the afternoon a party of 54 members and guests went to Portsmouth by automobile, where those interested visited the Portsmouth Navy Yard, at the invitation of the Commandant, and inspected the engineering work there. Another party visited the Memorial Bridge under construction in Portsmouth, and a third party was piloted by a guide about the City of Portsmouth which is famous for its old buildings and old architecture, all returning to the Hotel Wentworth at 6 P. M.

Tea-Dance

Wednesday, June 21st.—4 p. m.—A Tea-Dance was held in the Ball Room of the Hotel Wentworth for those who did not care to take the trip to Portsmouth.

Bridge Tournament

Wednesday, June 21st.—9 p. m.—A Bridge Tournament was arranged for the members and guests, and from 8:30 until 11:30 P. M., there was dancing, the music being furnished by the Boston Symphony Orchestra.

Excursion to Casco Bay

Thursday, June 22d.—Members and guests, numbering 131, were taken in automobiles to Portsmouth, where they boarded a special train at 9 A. M., for Portland, Me. Arriving at the wharf in Portland at 10:30 A. M., a steamer trip was taken around Casco Bay which is noted for its beautiful scenery, being dotted with many islands, on some of which are famous estates. At noon the party landed at Long Island, where an old-fashioned New England clambake was served to 148 members and guests, after which a sail around the Bay was enjoyed. At 4:00 P. M., the party returned to Portland and boarded the special train which arrived at Portsmouth at 6 P. M., returning by automobile to the hotel.

Reception

Thursday, June 22d.—9 p. m.—A reception was given, in the Ball Room of the Hotel Wentworth, to President and Mrs. Freeman, assisted by Past-President and Mrs. Webster. In the receiving line with them, was Capt. N. E. Irwin, U. S. N., Commandant of the Portsmouth Navy Yard. The reception was attended by 122 members and guests and was followed by dancing until midnight.

ATTENDANCE

The following 135 Members of the Society were in attendance. There were also present 88 ladies and guests.

Adams, H. S.........Arlington, Mass.
Allen, C. Frank.West Roxbury, Mass.
Allen, Kenneth.......New York City
Anderson, G. G...Los Angeles, Calif.
Andrews, Horace......Albany, N. Y.
Appleton, Thomas A....Salem, Mass.
Atwood, T. C......Chapel Hill, N. C.
Atwood, W. G........New York City

Banks, C. W...........Boston, Mass.
Barbour, F. A.........Boston, Mass.
Brace, J. H...Montreal, Que., Canada
Brooks, M. E..........Boston, Mass.
Brown, E. W...........Boston, Mass.
Brownell, E. H....Portsmouth, N. H.
Buck, H. R.........Hartford, Conn.
Bush, E. W.........Hartford, Conn.

Chandler, E. M.......New York City
Chase, J. C.............Derry, N. H.
Chase, W. H.....New Bedford, Mass.
Chester, J. N.........Pittsburgh, Pa.
Cole, Edward S.......New York City
Conant, E. R......Manchester, Mass.
Connelly, J. A.......New York City
Cowles, L. S...........Boston, Mass.
Cummings, R. A......Pittsburgh, Pa.
Curtis, F. S.............Boston, Mass.

Danforth, G. C.........Augusta, Me.
Darrow, F. T..........Lincoln, Nebr.
Davis, A. P.......Washington, D. C.
Davison, G. S........Pittsburgh, Pa.
Dean, A. W...........Boston, Mass.
Dean, Luther ....Taunton, Mass.
Duncan, J. H.........Searsport, Me.

Dunham, H. F.......New York City
Dyer, A. J..........Nashville, Tenn.

Eddy, H. P............Boston, Mass.
Emerson, G. C.........Boston, Mass.
Evans, R. H.........Haverhill, Mass.
Everett, F. E.........Concord, N. H.

Fay, F. H..............Boston, Mass.
Ferguson, J. N..........Boston, Mass.
Freeman, J. R......Providence, R. I.

Gray, A......St. John, N. B., Canada
Grover, W. A...........Dover, N. H.
Grunsky, C. E...San Francisco, Calif.
Guppy, B. W...........Boston, Mass.

Haas, E. F.....San Francisco, Calif.
Hageman, H. A........Boston, Mass.
Haines, E. G...Richmond Hill, N. Y.
Hale, R. A..........Lawrence, Mass.
Hamilton, P. D. G......Boston, Mass.
Hammond, G. T.....Brooklyn, N. Y.
Harte, C. R.......New Haven, Conn.
Hatt, W. K........Washington, D. C.
Henny, D. C..........Portland, Ore.
Hilton, H. L.......Cambridge, Mass.
Hodgdon, F. W.....Arlington, Mass.
Holden, C. A.........Hanover, N. H.
Honens, F. W...........Sterling, Ill.
Hough, L. C...........Boston, Mass.
Houston, W. O.......Jackson, Mich.
Howe, E. W...........Boston, Mass.
Howe, J. M...........Houston, Tex.
Hoyt, J. C........Washington, D. C.
Hoyt, L. B............Melrose, Mass.
Humphrey, Richard L.
Philadelphia, Pa.

Johnston, J. A......Worcester, Mass.

Kennison, K. R........Boston, Mass.

LeBaron, J. F...........Essex, Mass.
Lewis, E. W........Springfield, Mass.
Lovett, G. F............Berlin, N. H.
Loweth, C. F............Chicago, Ill.

McClintock, J. R...Kansas City, Mo.
McComb, D. E.....Washington, D. C.
McGrew, A. B.........Pittsburgh, Pa.
McVea, J. C...........Houston, Tex.
Marsden, R. R.......Hanover, N. H.
Marston, Anson..........Ames, Iowa
Marston, F. A..........Boston, Mass.
Metcalf, Leonard ....Boston, Mass.
Modjeski, Ralph ......New York City
Morse, W. P.....West Newton, Mass.
Moss, C. P.........Yankton, S. Dak.

Noble, F. C..........New York City
Norris, W. H..........Portland, Me.
Northrop, A. A........Boston, Mass.

Patton, R. S......Washington, D. C.
Pegram, G. H........New York City
Pierce, C. H...........Boston, Mass.
Pratt, A. H...........Newark, N. J.

Ralston, J. C.........Spokane, Wash.
Reeves, W. F.........New York City
Richmond, A. P......Hanover, N. H.
Ridgway, Robert.....New York City
Robinson, A. W....Upper Melbourne, Que., Canada
Robinson, R. M........Hudson, N. Y.
Rogers, E. H.....West Newton, Mass.
Rollins, J. W., Jr.......Boston, Mass.
Ruggles, A. V........Cleveland, Ohio

Sanborn, F. B..........Boston, Mass.
Sargent, P. D..........Augusta, Me.
Saville, C. M........Hartford, Conn.
Scheidenhelm, F. W...New York City
Shaw, A. L.........Auburndale, Mass.
Shaw, P. A........Manchester, N. H.
Shedd, G. G.......Manchester, N. H.
Shelley, H. T.......Philadelphia, Pa.
Skinner, J. F........Rochester, N. Y.
Snow, J. B........Forest Hills, N. Y.
Spofford, C. M......Cambridge, Mass.
Starr, H. H........Germantown, Pa.
Stearns, R. H........New York City
Stepath, Charles....Springfield, Mass.
Swain, G. F........Cambridge, Mass.
Sweetser, E. O.........St. Louis, Mo.

Uhl, W. F.............Boston, Mass.

Van Cleve, H. P...... New York City
Voss, Walter C...... Brookline, Mass.

Waddell, J. A. L...... New York City
Waldron, S. P.......... Boston, Mass.
Wall, Edward E....... St. Louis, Mo.
Wardle, E. B..... Grande Mere, Que., Canada
Webster, G. S....... Philadelphia, Pa.
Wheeler, W. S.......... Dover, N. H.
Whipple, G. C...... Cambridge, Mass.
Widdicombe, S. H.. Springfield, Mass.
Wiggin, T. H......... New York City
Wight, F. C.......... New York City
Wilcock, Frederick .. Brooklyn, N. Y.
Wing, C. B.......... Palo Alto, Calif.
Winn, G. P........... Nashua, N. H.
Winsor, F. E....... Providence, R. I.
Wood, Dana M......... Boston, Mass.

Yates, J. J......... Jersey City, N. J.
Young, Roscoe C.... Marquette, Mich.

MINUTES OF MEETINGS OF SPECIAL COMMITTEES TO REPORT ON ENGINEERING SUBJECTS

Special Committee on Specifications for Bridge Design and Construction

June 9th, 1922.—The Eighth Meeting of the Special Committee was called to order at the Headquarters of the Society at 10:30 A. M. Present, Henry B. Seaman (*Chairman*), V. H. Cochrane, O. E. Hovey, C. W. Hudson, M. S. Ketchum, J. E. Greiner, J. H. Ames, S. B. Slack, E. F. Kelley, and H. C. Baird (*Secretary*).

On motion, duly seconded, the discussion of the Tentative Specifications for Steel Highway Bridges, the draft of which had been prepared by Professor Ketchum and Mr. Worcester, was taken up, and the entire morning session was devoted to the discussion of the question of Loading.

As no final agreement seemed to be possible, Chairman Seaman appointed Professor Ketchum and Mr. Kelley as a Sub-Committee to draft a Loading Specification for Highway Bridges, to be presented for discussion at the next meeting of the Committee.

The afternoon session was opened with a general discussion of the advisability of dropping the Highway Specifications, for the present, and revising the specifications for Steel Railway Bridges, in the light of the discussion presented before the Society at its regular meeting on June 7th, 1922.* On motion, duly seconded, it was decided to discuss the revision of the Railway Specifications with a view to presenting a report, if possible, to the Society at the next Annual Meeting.

Chairman Seaman proposed that a new specification prepared by him be placed before the Committee for discussion and revision in preference to the specification prepared and submitted to the Society by the Committee, and published in *Proceedings* for December, 1921. On motion, duly seconded, it was decided to discuss the new specification and the remainder of the meeting was devoted to this discussion.

June 10th, 1922.—The meeting was called to order at 9:30 A. M., at the Headquarters of the Society.

This session was devoted to a discussion of Unit Stresses and Details of Design for Steel Railway Bridges.

On motion, duly seconded, the Committee adjourned at 1 P. M., to meet in October, 1922, at the call of the Chair.

* See p. 1457 of Papers and Discussions.

ITEMS OF INTEREST

This Society is not responsible for any statement made or opinion expressed in its publications.

The Committee on Publications will be glad to receive communications of general interest to the Society, and will consider them for publication in *Proceedings* in "Items of Interest". This is intended to cover letters or suggestions from our membership concerning matters which are not of a technical character. Such communications, however, must not be controversial or commercial.

AWARD OF JOHN FRITZ MEDAL

The John Fritz Medal, awarded annually to engineers for achievement in applied science, has been conferred on Senator Guglielmo Marconi for his invention of Wireless Telegraphy.

The presentation ceremonies were held on Thursday evening, July 6th, 1922, at the Engineering Societies Building, New York City, following a dinner given in honor of Senator Marconi at the Engineers' Club. The speakers included James R. Sheffield, Esq., Professor Michael Pupin, and Dr. Elihu Thomson, who presented the medal to Senator Marconi.

Other distinguished engineers who have been awarded the John Fritz Medal, are:

John Fritz	1902	John Edson Sweet	1914
Lord Kelvin	1903	James Douglas	1915
George Westinghouse	1906	Elihu Thomson	1916
Alexander Graham Bell	1907	Henry Marion Howe	1917
Thomas Alva Edison	1908	J. Waldo Smith	1918
Charles Talbot Porter	1909	George W. Goethals	1919
Alfred Noble	1910	Orville Wright	1920
Sir William Henry White	1911	Sir Robert A. Hadfield	1921
Robert Woolston Hunt	1912	Charles P. E. Schneider	1921

DECORATIONS CONFERRED BY FRENCH GOVERNMENT

On Thursday, July 20th, 1922, Arthur S. Dwight, President of the American Institute of Mining and Metallurgical Engineers, and Charles F. Rand, Chairman of the Engineering Foundation, were decorated with the Croix de Chevalier de la Légion d'Honneur by the French Government, for distinguished service during the World War. The decorations were conferred by M. Gaston Liebert, Consul General of France, following a luncheon held at the Engineers' Club, New York City.

In presenting the decorations, Consul General Liebert eulogized Col. Dwight and Mr. Rand as personifying the spirit and service of the American engineer, which, he asserted, was a powerful factor in the victory over Germany.

ZONING

Mr. John M. Gries, Chief of the Division of Building and Housing, U. S. Department of Commerce, announces that the Advisory Committee, appointed by Secretary Hoover, has prepared a Zoning Primer and a selected Bibliography on Zoning, copies of which are available to engineers and others interested in that subject and can be obtained by applying to the Superintendent of Documents, Government Printing Office, Washington, D. C. The price is 5 cents.

HYDRAULIC LABORATORIES IN THE UNITED STATES

A Directory of Hydraulic Laboratories in the United States has been compiled under the direction of the Hydraulic Research Committee of Engineering Foundation, the members of which are J. Waldo Smith, M. Am. Soc. C. E., Chief Engineer, Board of Water Supply of the City of New York, and Silas H. Woodard, M. Am. Soc. C. E., Consulting Engineer, New York City. The book contains information concerning forty-nine laboratories in engineering colleges, industrial establishments, and Governmental bureaus. Only statements furnished by the person responsible for the laboratory have been used in each case. Indirectly, this information affords a comparison of equipment in the various laboratories and, in some instances, suggests possibilities of greater usefulness. The information will be helpful to those contemplating the establishment of new laboratories, to persons desiring to have hydraulic tests or experiments performed, and to students choosing schools in which to pursue the study of Hydraulic Engineering.

Any one desiring copies of the Directory of Hydraulic Laboratories, or more information regarding Engineering Foundation, should address Alfred D. Flinn, Secretary, 29 West 39th Street, New York City.

ACTIVITIES OF LOCAL SECTIONS*

Meetings of San Francisco Section

The regular meeting of the San Francisco Section was held on April 20th, 1922, at the Engineers' Club; President Thomas H. Means in the chair; H. D. Dewell, Secretary; and present, also, 140 members and guests.

The Business Meeting followed a dinner at which the 77 members and guests present were entertained by selections of music and speaking by radio through the courtesy of the Pacific Radio Trade Association.

Immediately following the dinner, President Means delivered his Inaugural Address.

The Secretary presented a communication from Mr. Paul Bailey, Deputy Chief, Division of Engineering and Irrigation, State Department of Public Works, on the subject of the Water Resources Investigation authorized by the State Legislature of 1921, suggesting that the Consulting Board meet with the Section and the San Francisco Section of the Mechanical Engineers to discuss the matter. On motion, duly seconded, the matter was made a subject for discussion at the regular June meeting of the Section.

Correspondence was presented from Acting Secretary Chandler of the Society relative to sets of *Transactions* available for distribution to Local Sections, and also stating that copies of the Society *Proceedings* would be mailed regularly to such Local Sections as maintained a library. It was announced that unless objections were offered, the Board of Directors would order a set of *Transactions* and would make arrangements to have them placed on file at the Engineers' Club.

Announcement was made that the following papers: (1) An Analysis of Changes Made in the A. I. A. Documents; (2) A Proposed Universal Form of Contract Agreement as Applied to Building Work; and (3) A Proposed Universal Form of Contract Agreement as Applied to Railroad Work, had been received from Acting Secretary Chandler in response to a request from the Section, and that these papers had been referred by the Board of Directors to a Special Committee consisting of Messrs. Thurston, Vensano, and Kirkbride for study and comment.

The Secretary announced that a Special Meeting of the Section would be held on the evening of May 8th, 1922, to hear Professor Duff A. Abrams, M. Am. Soc. C. E., speak on "Scientific Methods of Making Concrete".

Mr. A. H. Markwart, Chairman of the Committee on General Arrangements for the Fall Meeting of the Society, presented a synopsis of the preliminary report of his Committee.

Mr. C. E. Grunsky reviewed the Spring meeting of the Society held in Dayton, Ohio, in April, stating that the meeting was a distinct success, and Director W. L. Huber also presented a brief review of the sessions and excursions at that meeting.

Mr. B. F. McNamee, Radio Engineer, delivered a lecture on "The Development of Communications by Radio from its Discovery to the Present Time", and also described many of the uses to which it is now put.

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* For list of Local Sections, Officers, etc., see p. 508.

A paper by Mr. E. E. Carpenter entitled, "The Design and Construction of the Stanford Stadium", was presented, in the absence of Mr. Carpenter, by his associate, Mr. Shirley Baker.

Special Meeting of May 8th, 1922

A special meeting of the Section was held at the Engineers' Club on May 8th, 1922; Vice-President G. A. M. Elliott in the chair; H. D. Dewell, Secretary; and present, also, 58 members and guests.

Following the dinner, which was served at 6:30 p. m., Col. William G. Atwood, M. Am. Soc. C. E., Director of National Research Council, who was the guest of the Section, addressed the meeting on "Marine Borers".

The address of the evening was made by Professor Duff A. Abrams, M. Am. Soc. C. E., of Lewis Institute, Chicago, Ill., who discussed the "Scientific Method of Making Concrete".

Meeting of Atlanta Section

A meeting of the Atlanta Section was held at the Winecoff Hotel on June 12th, 1922; President William C. Spiker in the chair; Frederick H. McDonald, Secretary.

A vote was taken in the matter of the affiliation of the Society with the American Federated Engineering Society, the result being that, out of 16 Corporate Members present, the vote was 10 for and 4 against this action.

An address by Mr. B. M. Hall on some of the at present undeveloped resources of Georgia, was followed by a discussion by Mr. W. R. Neal, Chief Engineer of the State Highway Commission, who outlined the universal interest in all projects on the question of proper roads and made a plea for participation by all public-spirited bodies in the furtherance of this general movement.

Meeting of Cleveland Section

A meeting of the Cleveland Section was called to order at 12:15 p. m., at the Hotel Winton, on May 10th, 1922; President A. V. Ruggles in the chair; George H. Tinker, Secretary; and present, also, 14 members and guests.

The minutes of the meeting of April 12th, 1922, were read and approved.

The Secretary presented a communication from *Engineering News-Record* in reference to biographies of engineers in civic work, and on motion, duly seconded, the President was instructed to appoint a committee of three to secure information and make recommendations on this subject.

A communication from Acting Secretary Chandler in reference to securing new members, was presented by the Secretary, and on motion, duly seconded, the President and Secretary were instructed to reply to the communication to the effect that it would appear unwise to solicit new members until the internal affairs of the Society are in a settled condition.

On motion, duly seconded, President Ruggles was instructed to appoint a committee of three to prepare a list of candidates and report at the September meeting of the Section.

The Secretary announced that the Executive Committee had selected Mr. W. E. Pease as Vice-President to fill the vacancy caused by the death of Mr. F. E. Bissell.

The report of the River and Harbor Committee was placed before the meeting and the Secretary presented a letter from the Chamber of Industry. After a short discussion by Messrs. Evers, Thomas, Pease and others, it was voted that Messrs. E. B. Thomas, F. D. Richards, W. E. Pease, and A. W. Zesiger be added to the River and Harbor Committee and that the Committee be requested to review its conclusions and submit a further report at the September meeting.

On motion, duly seconded, it was decided to lay the matter on the table until the September meeting of the Section.

Meeting of Detroit Section

On May 13th, 1922, and preceding the meeting of the Section, an inspection trip to the three power plants along the Huron Valley was made by members of the Section from Ann Arbor and Detroit. The party, under the guidance of Mr. Gardner S. Williams, visited the water-power developments of Superior, Geddes, and Barton. The history of these plants was recited by Mr. Williams in their relation to the Detroit Edison and Commonwealth power developments, and furnished an introduction for the address of the evening. The power plant at the University of Michigan was also visited, as well as the Naval Testing Tank in the Engineering Building, and Professor Sadler, of the Department of Marine Engineering and Naval Architecture, gave a most entertaining talk on the construction of the models used in the testing tank, describing the practical applications and the usefulness of the tests in the economy of marine engineering. About 30 members took part in this excursion.

The meeting was called to order, after a dinner at the Michigan Union, Ann Arbor, Mich., at which Mr. E. M. Walker presided, 22 members being present. Following a brief address of welcome by Prof. Gram to the Detroit members, and a description of the functions and purpose of the Michigan Union, an inspection of the building itself was made.

An address on the subject of "A Super Power System for Detroit and Chicago" was presented by Mr. Gardner S. Williams, which was followed by a brief discussion of power developments in general, the proposed Atlantic Seaboard Super Power System, and the St. Lawrence developments.

Meeting of Duluth Section

The Annual Meeting of the Duluth Section was called to order at 12:15 P. M., on May 15th, 1922; President John L. Pickles in the chair; W. G. Zimmermann, Secretary; and present, also, 21 members and 3 guests.

The guests, Messrs. George M. Hunt, in charge of Wood Preservation at the Forest Products Laboratory at Madison, Wis., J. H. Taylor, Chief of Fire Prevention, Great Northern Railway, and C. L. Seymour, Universal Portland Cement Company, Minneapolis, Minn., were introduced by President Pickles.

The minutes of the meeting of April 17th, 1922, were read and approved.

The Secretary presented a letter from George H. Herrold, M. Am. Soc. C. E., First Vice-President of the Northwestern Section, calling attention to the meeting of that Section on May 19th, 1922, at which Gardner S. Williams, M. Am. Soc. C. E., will speak on Society activities.

A letter from Acting Secretary Elbert M. Chandler of the Society relative to a set of *Transactions* for the Library of the Section, which was referred to the Library Committee, was presented, as well as one asking for a copy of the paper recently presented before the Section by Mr. W. A. Clark on the subject, "Standardization". This letter was referred to Mr. Clark.

A check for $37 covering the allotment for dues of members of the Section, in accordance with the recent action taken by the Board of Direction, was received from Acting Secretary Chandler.

Treasurer Carson presented his Annual Report, showing a balance on hand for the year ending May 1st, 1922, of $192.04. On motion, duly seconded, the report was received with thanks and accepted subject to the approval of the Auditing Committee.

The following officers were elected for the ensuing year: President, William H. Hoyt; First Vice-President, Thomas F. McGilvray; Second Vice-President, O. H. Dickerson; Secretary, Walter G. Zimmermann; and Treasurer, John Carson. These, with the two last Presidents, Messrs. Clark and Pickles, constitute the Board of Directors for the coming year.

The meeting was then turned over to the Entertainment Committee and Chairman Dickerson introduced Mr. C. deB. Christie, who presented an interesting and instructive address on the subject of "Notes on Emergency Dams for Lock Canals", illustrating his remarks with photographic pictures. On motion, duly seconded, a vote of thanks was given Mr. Christie for his interesting paper.

Organization Meeting of Lehigh Valley Section

The final organization of the Lehigh Valley Section was effected at a meeting held at the Bethlehem Club, Bethlehem, Pa., on June 5th, 1922, at which there were present 21 members of the Society and 7 members of Student Chapters.

The following officers were elected to hold office until the Annual Meeting of the Section to be held in December, 1922: President, George H. Blakeley; Vice-Presidents, Messrs. B. C. Collier, Thomas Earle, and F. O. Dufour; and Secretary-Treasurer, M. O. Fuller.

Meetings of Los Angeles Section

A meeting of the Los Angeles Section was held at the City Club on May 10th, 1922; President Ralph J. Reed in the chair; F. G. Dessery, Secretary; and present, also, 52 members and 18 guests.

President Reed introduced William Mulholland, M. Am. Soc. C. E., who addressed the meeting in favor of "The Proposed Water and Power Act", and the subject was also discussed *pro* and *con* by Messrs. G. S. Binckley,

F. D. Howell, Burdett Moody, Frederick Eaton, Luther G. Brown, A. L. Sonderegger, S. A. Jubb, Charles H. Lee and F. E. Trask.

Mr. George G. Anderson reviewed the Spring Meeting of the Society held at Dayton, Ohio, and, with Past-President Dennis, called attention to the quarterly meeting to be held in San Francisco, Calif., in October, 1922.

MEETING OF JUNE 14TH, 1922

A meeting of Los Angeles Section was held at the City Club on June 14th, 1922; Past-President H. Hawgood in the chair; F. G. Dessery, Secretary; and present, also, 28 members and 18 guests.

Mr. R. E. Brownell, Secretary of the Oklahoma Section, was introduced, among others, as the guest of the Section.

On motion, duly seconded, the following resolution was unanimously adopted:

"*Whereas,* The topographical maps of the area of Los Angeles County between the mountains and the seashore, prepared prior to 1898 by the United States Geological Survey, are obsolete, lacking in detail, and do not show the improvements made subsequent to 1898; and

"*Whereas,* The cost of field and office work to bring these maps up to date has been estimated at $120 000; and

"*Whereas,* The United States Geological Survey agrees to perform the office work and printing of these maps at an estimated cost of $30 000, conditioned on Los Angeles County financing the cost of the field work and surveys, estimated at $90 000;

"*Therefore, Be It Resolved,* That the members of the Los Angeles Section, American Society of Civil Engineers, respectfully request the Board of Supervisors of Los Angeles County to include in the current budget and subsequent budgets sufficient finances to inaugurate this important work at an early date."

Motion pictures showing interesting views of the Miami Conservancy District improvements and of members present at the Quarterly Meeting of the Society at Dayton, Ohio, were shown.

The speaker of the evening, Mr. W. W. Lawton, a member of the Institution of Mechanical Engineers, addressed the meeting on "Ancient and Modern Engineering in India and Ceylon", illustrating his remarks with lantern slides and describing the works in detail. At the conclusion of his address, Mr. Lawton was extended a rising vote of thanks.

Annual Meeting of New York Section

The Annual Meeting of the New York Section was held at the Engineering Societies' Building, on May 17th, 1922; President Nelson P. Lewis in the chair; J. P. J. Williams, Secretary; and present, also, about 135 members and guests.

The Annual Reports of the Standing Committees and the report of the Treasurer were read and accepted.

The Secretary announced that at the last meeting of the Board of Directors a resolution was passed, expressing its appreciation of the work of the Standing Committees during the past year. It was also decided to decline the invitation to become a member of the Committee on City Departments.

President Lewis then called for the report of the Nominating Committee, which was as follows: President, J. Vipond Davies; First Vice-President, Frederick C. Noble; Second Vice-President, Charles W. Leavitt; Secretary, Harold M. Lewis; Treasurer, Charles R. Hulsart; and Directors, William G. Grove and Waldo C. Briggs. The nominees were unanimously elected and the retiring President introduced Mr. Davies, who took the Chair.

The subject for the evening was "The Need of Regional Planning for the New York District", discussion on which was opened by Mr. Charles D. Norton, Chairman of the Committee of the Russell Sage Foundation on Plan of New York and Its Environs. Mr. Norton referred to the meeting on May 10th, 1922, at which the formation of this Committee was announced, and expressed the danger of arousing expectations which, in the nature of things, cannot be realized. He stated that there could not be any plan of New York unless it were a regional plan and that the burden of the development of such a plan rests heavily on the engineers. He recalled the fact that the Committee, of which he was Chairman, which planned for Chicago, accomplished nothing until the members realized that they must plan, not for the city alone, but for all the territory in which Chicagoans were interested. That area is being studied in which New York may be said to reside, and includes all of Long Island and reaches to Bridgeport, beyond West Point, and from around near Princeton to the sea. He asked for the benefit of the co-operation and criticism of local engineers and expressed the hope that this will lead to the development of a plan that is creditable and that may at least spur others to do better.

Mr. Arthur S. Tuttle, Chief Engineer, Board of Estimate and Apportionment, described the development of the present plan of New York City, illustrating his remarks with lantern slides. He described the Borough of Manhattan as the natural clearing house for vehicular traffic to and from the city, and stated that it was fortunate that the initial step toward formulating a street plan was taken before development was far advanced. He described the map of 1811 and its connection with the earlier plan. Although it is customary to regard Broadway, and parts of Fourth Avenue, Fifth Avenue, Seventh Avenue, and Riverside Drive as the main arterial north and south streets, there are other streets which, unfortunately, have been largely blocked by the short-sighted policy of permitting them to be occupied by elevated railroads. Mr. Tuttle thinks the next step toward the relief of Manhattan congestion should be through restoring these latter streets to the use for which they were originally planned. He described the great advantages of consolidation in the planning of the city, as there is now an orderly treatment of undeveloped areas, even in advance of the laying down of a map.

Mr. Harold M. Lewis, of the staff of the Committee on the Plan of New York and Its Environs, presented a number of slides showing what had already been done toward a physical survey of the area to be studied. This covered such subjects as the densities of population—past and estimated—and the existing facilities in the way of railroads, highways, parks, sources of water supply, and sewage disposal.

Mr. Jay Downer, Engineer and Secretary of the Bronx Parkway Commission, outlined the needs in Westchester County, and the progress already made. He referred to the Westchester County Transit Commission, the County Government Commission, and the newly appointed Westchester County Park Commission. Slides were shown, showing the importance of the Mohansic Reservation and the proposed Peekskill-Bear Mountain Bridge in the development of a comprehensive park system for the County.

Mr. Morris R. Sherrerd, Consulting Engineer, of Newark, N. J., outlined the development of the New Jersey Metropolitan District, referring to the growth of the city planning movement which started in cities and, later, expanded to counties, and now includes even States. He made a plea for the power of excess condemnation as an aid to adequate city planning.

Mr. Bertram H. Saunders, Chairman of the City Planning Commission of Paterson, N. J., spoke of the developments of city planning in that city. The original plan was made by Maj. l'Enfant in 1792, the principal feature of which was a fine civic center with radiating boulevards. This plan was not carried out, but the growth of the city is now being guided by an effective City Planning Commission.

Mr. Nelson P. Lewis was called on to speak as the one who had been directing the engineering work done for the Committee on Plan of New York and Its Environs. He stated that little more had been done thus far than to make an inventory of existing conditions, and emphasized especially the fact that the last thing that was intended was to impose a super-planning body on the district or to usurp any local rights. It is desired to plan something that will be useful to every one, and any constructive suggestions will be welcomed.

Mr. Flavel Shurtleff, Secretary of the National City Planning Conference and American City Planning Institute, stressed the importance of the city planning movement and the need for the help of engineers to make it successful.

Mr. Robert Ridgway brought before the Section the resolution passed by the Board of Direction of the Society that the attention of each Local Section be called to the responsibility resting on the sponsors for applicants for membership, and asked for co-operation in maintaining the high standard of membership.

Third Sub-Section Conference on Design

At 5:15 P. M., preceding the Annual Meeting, the third of the series of Sub-Section Conferences was held, James H. Edwards, Assistant Chief Engineer of the American Bridge Company, presiding, and about 30 members present.

The subject, "How Much Detail Should be Included in Specifications?", was discussed by several members. It was suggested that present specifications are too long and much of them could be omitted. On motion, duly seconded, a resolution was passed urging the Section to exert its influence for such reform in building laws and engineering practice as would make it impossible for any building in this Metropolitan District, where public safety is involved,

to be opened to public use until a competent structural engineer had certified to its safety and stability.

Meeting of Northeastern Section

The regular meeting of the Northeastern Section was held on June 3d, 1922, at 1:15 P. M., at the Boston City Club, Boston, Mass.; Chairman F. B. Sanborn, presiding; Charles W. Banks, Secretary; and present, also, 46 members and 2 guests.

The meeting was arranged as a Round Table Luncheon, at which the guests were Acting Secretary Elbert M. Chandler, of the Society, and Director Frank E. Winsor. The luncheon was followed immediately by the business meeting of the Section.

The Secretary reported briefly on the meetings held to date, the present membership, the financial standing of the Section, and the proposed affiliation of the Technical Societies of Boston.

Chairman Sanborn introduced Director Frank E. Winsor, of District No. 2, who addressed the meeting on the Federated American Engineering Societies. In this connection, the question as to whether the Society should join the Federation was discussed by Messrs. Barbour, Metcalf, Hale, Porter, and others, and Acting Secretary Chandler answered several questions relative to the probable expense. As a result, a vote was called for by the Chairman. Of the 45 members present at the time of voting, 25 voted in favor, 1 against, and 19 did not vote. The Secretary announced that of the 530 cards sent to members of the Section, 48 had been returned, of which 22 voted in favor of joining, and 1 against, the others not voting.

After some discussion on the proposed affiliation of the Technical Societies of Boston by Messrs. Sanborn, Cunningham, Cameron, Metcalf, and others, it was unanimously decided, on motion, duly seconded, that the Section join the Affiliated Technical Societies of Boston.

On motion, duly seconded, the Treasurer was authorized to pay the amount of indebtedness due the Boston Society of Civil Engineers.

On motion, duly seconded, the Executive Committee was empowered to make the necessary arrangements to discontinue the affiliation with the Boston Society of Civil Engineers, and to prepare and present to the membership, in proper form, as provided in the Constitution and By-laws of the Section, the amendments necessary to effect the details of joining the Affiliated Societies.

Speaking in regard to the Annual Convention, the Acting Secretary presented briefly the plan for that Convention, and expressed the hope that the Boston members would support it. He also mentioned several ways in which the Society has been working for the good of non-resident members, such as the improvements in *Proceedings,* the allocation of funds to Local Sections, the holding of Board meetings in different localities, the addition of two technical meetings each year, and the sending of the Secretary to visit the Local Sections.

New Officers of Philadelphia Section

At the regular meeting of the Philadelphia Section held on June 5th, 1922, the following officers were elected for the ensuing year: President, William Easby, Jr.; Vice-President, Henry J. Sherman; Secretary and Treasurer, Charles H. Stevens; and Directors, R. G. Develin and Walter S. Miller.

Meeting of Portland Section

A meeting of the Portland Section was held at the University Club on April 21st, 1922; President F. M. Randlett in the chair; C. P. Keyser, Secretary; and present, also, 40 members.

The minutes of the meeting of March 17th, 1922, were read and approved.

Mr. G. B. Hegardt presented a brief account of the visit by a party of members of the Section to the Engineering School of the Oregon Agricultural College on April 1st, 1922, and, on motion, duly seconded, a recommendation that the Section schedule a Spring Meeting with the Student Chapter at the College was referred to the Program Committee.

The Secretary presented an invitation from the Portland Section of the American Institute of Electrical Engineers to attend the meeting of that Section to be held on April 26th, 1922, and, on motion, duly seconded, the Secretary was instructed to mail notices of this meeting to the members of the Section.

The address of the evening was made by Mr. J. P. Newell, who discussed the subject, "The Analysis of Railway Freight Transportation", illustrating his remarks with charts and diagrams.

Annual Meeting of the Providence Section

The Annual Meeting of the Providence Section was held at the University Club, on May 23rd, 1922; Chairman Sydney Wilmot, presiding; and Robert L. Bowen, Secretary.

The following officers were elected for the ensuing year: Chairman, Sydney Wilmot; Vice-Chairman, Irving W. Patterson; Secretary-Treasurer, Robert L. Bowen; and Directors, Frank E. Winsor and Thomas H. Coe.

Mr. Elbert M. Chandler, Acting Secretary of the Society, who was present as a guest, addressed the Section, outlining the work which the Society has under way and in prospect, and discussing the arrangements of the Annual Convention to be held at Portsmouth, N. H.

The Secretary rendered his report, in the course of which it was stated that the Section had held nine meetings during the year, at all of which addresses were made on various subjects by prominent engineers.

At the close of the Annual Meeting, a Joint Meeting was held with the Structural Section of the Providence Engineering Society, at which Mr. Albert A. Northrop, of Boston, Mass., gave an illustrated talk on the "Carribou Power Plant Development."

Meetings of Seattle Section

In lieu of the May meeting of the Section, the members made an inspection trip to the Skagit River Power Project, under the direction of Mr. A. H. Dimock, City Engineer, and Mr. C. F. Uhden, Chief Engineer of the Project.

The trip was made by automobile to Rockport, Wash., and from there to the site of the operations on the municipal construction railway. The party numbered 45, and included about 20 members of the Student Chapter of the University of Washington.

The first day was devoted to an inspection of the tunnel, power-house site, and the construction power plant and camp. On the following day, a trip was made to the site of the main dam on the Skagit, and from there up to the canyon (which is accessible only by trail), a distance of seven miles.

The party returned home on the third day, making a stop at the plant of the Portland Cement Association at Concrete, Wash., where luncheon was served and an inspection of the plant and quarry was made.

Meeting of June 26th, 1922.

The meeting of the Section was called to order on June 26th, 1922; President F. F. Sinks in the chair; and Frank H. Fowler, Secretary.

The minutes of the April meeting were read and approved.

A letter from the Student Chapter of the University of Washington, thanking the Section for the courtesies extended to the students in connection with the trip to the Skagit River Power Project was read, and on motion, duly seconded, was ordered filed.

On motion, duly seconded, a resolution was passed, extending the thanks of the members of the Section to Messrs. Dimock and Uhden for their courtesies and efforts in behalf of the Section during the trip to the Skagit River Power Project.

An interesting address on the "Columbia River Basin Project" was made by Mr. A. J. Turner, formerly Chief Engineer on the Project, who illustrated his remarks with a number of lantern slides. At the conclusion of his address, Mr. Turner was extended a vote of thanks by those present at the meeting.

Meeting of Spokane Section

The regular meeting of the Spokane Section was held at the East Banquet Annex, Davenport's, on February 10th, 1922; Vice-President B. J. Garnett in the chair; Charles E. Davis, Secretary; and present, also, 8 members and 2 guests.

On motion, duly seconded, the Committee in charge of possible entertainment of General Goethals was asked to continue.

The question of the Society joining the Federated American Engineering Societies was taken up, and it was the unanimous opinion of all members present that the Society should join the Federation.

Meeting of Virginia Section

A Joint Meeting of the Virginia Section and the Virginia Sections of the American Society of Mechanical Engineers, the American Institute of Elec-

trical Engineers, the Society for the Promotion of Engineering Education, and the Richmond Chapter of the American Association of Engineers, was held at the University of Virginia at Charlottesville, Va., on May 5th, 1922.

At the morning session which was called to order at 10 A. M., the meeting was addressed by Mr. E. W. James, Assistant Chief Engineer, U. S. Bureau of Public Roads, on the subject "The Standardizing of Highway Specifications".

A business meeting was called to order at 1:30 P. M., at the Colonnade Club; President J. C. Carpenter in the chair; Tazewell Ellett, Secretary *pro tem.;* and present, also, 9 members and 2 guests.

After a discussion on the desirability of holding Section meetings with the American Society of Mechanical Engineers, it was decided, on motion, duly seconded, that joint meetings of the Virginia Sections would be held at Norfolk, Va., in the fall, and also at Lexington, Va.

On motion, duly seconded, the President was authorized to appoint a Program Committee of three members.

A vote of thanks was tendered, on motion, duly seconded, to Mr. James for his participation in the meeting.

On motion, duly seconded, the *Journal of Engineering* of the University of Virginia, was adopted as the official publication of the Section.

The evening session was held as a Joint Meeting with the Student Chapter of the Society of the University of Virginia, 7 members of the Chapter being present. President Smith, of the Student Chapter, introduced the members of the Virginia Section and several short addresses were made, extending to the Student Chapter offers of assistance in its work, together with helpful suggestions.

ENGINEERING SOCIETIES EMPLOYMENT SERVICE

An Engineering Societies Service Bureau was established December 1st, 1918, as an activity of Engineering Council. It was managed by a board made up of the Secretaries of the four Founder Societies, and funds for its maintenance were provided by these Societies. On January 1st, 1921, this Bureau was taken over by The Federated American Engineering Societies and was known as the Employment Service of that organization. Recently, the management of the Service has been assumed by the Founder Societies. The service is co-operating with engineering organizations in all parts of the country and is desirous of increasing such co-operation by working with local engineering associations and clubs. Members of the American Society of Civil Engineers who desire to register should apply for further information, registration forms, etc., to Walter V. Brown, Manager, Engineering Societies Building, 29 West 39th Street, New York City. In order to be included in the list of "Men Available" published in *Proceedings,* copy must be received on or before the first of each month. All communications should be addressed to Mr. Brown.

EMPLOYMENT BULLETIN

POSITIONS AVAILABLE

YOUNG MAN to supervise the grinding of manganese castings. Applicant must have had experience in this work. Location, Ohio. V–258.

SALES ENGINEERS for New York, Pittsburgh, and Detroit. Every new man taken on will put in a period of from 1 to 3 months in the shop as an ordinary workman doing work that will be of value to him as a Salesman, after which he will be put in the field on actual erection of product for a similar period, following this will be put in Cleveland Office for a sufficient length of time to become familiar with forms and general policies. After this period will be put in one of our offices which are already established as a Junior Salesman, after which time salary will be determined by results. As we are contemplating opening new offices in Boston, Philadelphia, Buffalo, Chicago, and Cincinnati, during the course of the next two years, every man in Sales Department will have opportunity of qualifying for position of District Manager. Application by letter. Location, New York, Pittsburgh, and Detroit. Headquarters, Cleveland. V–1229.

SUPERINTENDENT ON CONSTRUCTION. After first year, if satisfactory, will be put in charge of office in another district. Must be able to handle men, meet others, and make a place for himself in community. Must be American and also not a radical. Application by letter. Salary not stated. Location, South Dakota. V–1322.

CONSTRUCTION SUPERINTENDENT experienced on fireproof apartment house work. Wanted at once. Application in person. Salary not stated. Location, New York City. V–1334.

RESIDENT ENGINEER for real estate development company to take charge of sewers, water supplies, streets, etc. Must live on property. Single man preferred. Application by letter. Location, New Jersey. V–1372.

CHEMICAL ENGINEER who has had actual experience in putting up naphtalene plants. Application by letter. Salary not stated. Location, New York City. V–1627.

GRADUATE ENGINEER, about 30 years of age, with experience in production, cost accounting, and manufacturing details by a nationally known corporation. Duties will be confined wholly to field work among a number of factories studying conditions and making recommendations for betterments in methods, equipment, and personnel. Application by letter. Salary not stated. Location, Canada. V–1710.

YOUNG BOY for File Clerk in Blue-Print Room. Print titles with printing machines, etc. Good opportunity for right man in large office just opened. Application in person. Location, New York City. V–1765.

SALESMAN experienced in selling steam specialties to handle old established line in Metropolitan District. Application by letter. Commission and salary. Headquarters, New York City. V–1766.

TRANSITMAN OR LEVELMAN, 3 months' work. Application in person. Salary $30. Location, New York City. V–1768.

ARCHITECTURAL DRAFTSMAN experienced along general planning lines. Application in person. Location, New York City. V–1773.

FILE CLERK AND TECHNICAL LIBRARIAN for engineering office. Application in person, New York City. Location, Texas. V–1779.

STRUCTURAL ENGINEER. Salary would be commensurate with ability to meet requirements. Application by letter. Location, New York City. V–1753.

PHYSICS INSTRUCTOR to start work September 1st. Only two classes of men considered, those who have had teaching experience and expect to continue in the profession, and those who have had good engineering training and engineering experience, but who plan definitely to go into teaching to stay. Takes at least two years to break a good man in on work, and it is impossible that we should knowingly employ a man who does not take teaching seriously. Application by letter. Location, Northeast. V–1755.

ENGINEER for Chair of Civil Engineering. One who has had some successful teaching experience, who is well grounded in scientific theory, and who is an administrator. Good personality. School of 1 000 students, which is growing rapidly. Prefer some one who is now the head of a department in one of leading universities or who may be second man in such a department. Age between 30 and 40. Application by letter. Salary not stated. Location, Northeast. V–1760.

INSPECTOR for 60-inch concrete sewer. Must be able to give grades and run transit. Application by letter. Location, New York State. V–1806.

BUILDING SUPERINTENDENT. Application in person. Location, New York City. V–1852.

CHIEF ENGINEER for manufacturers of conveying machinery. Chief Engineer or Chief Draftsman, well experienced in layout construction and details of conveying machinery of various types. Capable of taking complete charge of Drafting Department. Unusual opportunity offered to right man. Personal interview will be arranged. Give experience, age, and salary expected. Application by letter. Location, Missouri. V–1856.

SALES ENGINEER preferably with railroad experience for partnership in an established business handling domestic and export sales. $5 000 investment required. Application by letter. Location, New York City. V–1865.

STRUCTURAL DESIGNER for structural steel and reinforced concrete design on all types of buildings and general plant layouts. Application by letter, stating experience, salary, and earliest reporting date. Location, New York City. V–1866.

ESTIMATOR on structural and ornamental steel. Capable of taking full charge of estimating and securing contracts. Good opportunity to become Manager of plant. Experienced men only need apply. State age, education, experience, and salary desired. Application by letter. Location. New Jersey. V–1868.

STRUCTURAL STEEL DRAFTSMEN experienced on buildings and bridges. Positions at the plants or in New York offices. Location, New York City and Eastern United States. Application in person. V–1873.

YOUNG ENGINEER, with architectural experience, or steel concrete or wood experience for engineering and selling work. Application by letter. Salary, $125 Mo. Location, New York City. V–1877.

RECENT GRADUATE desirous of taking up planning, scheduling, and standardization work with large printing industry. Application by letter. Location, Pennsylvania. V–1878.

ENGINEERS who have made a specialty of asphalt paving and road construction, and who are familiar with handling of asphalt in various types of modern pavements. Location, Foreign Country. V–1879.

INSTRUCTOR in Electrical Engineering beginning September 20th. Must be graduate in Electrical Engineering and be able to teach fundamentals of electrical engineering in class and laboratory. One or two years' practical experience necessary. Application by letter giving full particulars and references. Location, Mid-West. V–1893.

MEN AVAILABLE

CIVIL ENGINEER AND CONSTRUCTION MANAGER at present completing construction of large industrial plant, having made a record in low cost and speed on reinforced concrete structures. Twenty-five years' experience in construction of industrial plants. Buildings, railroads, sewers, and water-works. CE–340.

EXECUTIVE ENGINEER, Assoc. M. Am. Soc. C. E.; age 40; married. General industrial and commercial training of responsible nature. Experience: Engineer with contractors; Superintendent of Construction for large manufacturing corporation; Chief Engineer in Far East, for well known oil company; Executive Engineer and Foreign Representative, organization, sales (steel products, structural steel, heavy chemicals), prominent metal company. Excellent credentials. Further details on request. CE–341.

MILL ARCHITECT AND ENGINEER, Assoc. M. Am. Soc. C. E.; age 38; married. Fourteen years' experience designing pulp and paper mills with appurtenant hydraulic and steam-power developments. Capable of taking responsible charge of purchase and arrangement of equipment, architecture, structural design, power requirements, specifications, and contracts. CE–342.

CONSTRUCTION SUPERINTENDENT; Graduate Civil Engineer; age 37. Extensive experience in general contracting in responsible charge of bridges, dams, roads, industrial, power, and hydro-electric plants. Now employed, but available soon. Personal interview. Either domestic or foreign opening. CE–343.

EXECUTIVE ENGINEER AND MANAGER, M. Am. Soc. C. E.; married; with nearly 20 years' broad general, active experience

with large, high-voltage, hydro-electric systems, fully conversant to take charge of investigations, construction, and management. Fully equipped to employ men and use materials under the worst conditions met with in foreign countries and remote from manufacturers, and to maintain satisfactory operation. Can speak Spanish. At present, in senior position of British Government Service in Near East, but leaving shortly. Location anywhere. Salary $6 000. CE–344.

CIVIL ENGINEER, Assoc. M. Am. Soc. C. E.; age 40; married. Seventeen years' experience in miscellaneous engineering and construction work, including designs, heavy earthwork, railroad yards, and buildings, etc. Extensive steam and electric railway valuation and maintenance. Now employed in executive position with large utility property. Desires change. Will consider position with railway, industry, or contractor. Personal interview solicited. CE–345.

ENGINEER AND SUPERINTENDENT OF CONSTRUCTION, Assoc. M. Am. Soc. C. E.; Technical graduate; age 43. Desires position with engineering firm or contractor. Twenty years' varied experience in office and field as Engineer, Superintendent of Construction, and Executive, city improvements, water-works, streets and pavements, river and canal improvements, dredging, tunnels, deep foundations, steel and concrete structures, machinery, etc. Excellent record and reference. Available April 1st. CE–346.

ENGINEER-MANAGER, Assoc. M. Am. Soc. C. E., age 30, with thorough business training, desires permanent connection as Engineer or Executive with commercial, industrial, utility, or other organization where future advancement is possible. New York or Eastern States preferred. Now permanently employed in responsible charge. Water supply company operation and construction. CE–347.

CIVIL ENGINEER, Graduate, Cornell, Assoc. M. Am. Soc. C. E.; age 39; married. Eleven years in charge of design and construction of bridges, buildings, heavy timber and concrete construction, waterfront structures, nine years design; thorough office experience; effective organizer and executive; familiar with business forms and practice; open for immediate engagement. Clean record and good references. Eastern Pennsylvania or New York preferred. CE–348.

CIVIL ENGINEER, Assoc. M. Am. Soc. C. E.; age 36; married. Desires position as city engineer, resident engineer, city manager, or other engineering work. Eighteen years' experience in construction, including reinforced concrete, structural steel, soft ground tunneling, rock excavation, mining, dredging, railroad, sewer, street and coffer-dam construction, as Engineer and Superintendent. CE–349.

PLANT ENGINEER, Assoc. M. Am. Soc. C. E.; age 47. More than twenty-five years' works and office experience on designs, estimates, installation, and maintenance of large steelworks and shipyard plants. Good technical education and fully qualified for responsible position. Already served as Shop Superintendent, Chief Designer, and Chief Engineer. CE–350.

ANNOUNCEMENTS

The Reading Room of the Society is open from 9 A. M. to 6 P. M., and from 7 P. M. to 10 P. M., every day, except Sundays, New Year's Day, Washington's Birthday, Memorial Day, Fourth of July, Labor Day, Thanksgiving Day, and Christmas Day; during July and August, it is closed at 6 P. M.

FUTURE MEETINGS

September 6th, 1922.—8 P. M.—A regular monthly business meeting will be held, and a paper by D. B. Steinman, M. Am. Soc. C. E., entitled "Locomotive Loadings for Railway Bridges", will be presented for discussion.

This paper was published in *Proceedings* for May, 1922.

LOCAL SECTIONS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Section (Constitution Approved by Board, 1905).

Thomas H. Means, President; H. D. Dewell, Secretary-Treasurer, 503 Market Street, San Francisco, Calif.

Colorado Section (Constitution Approved by Board, 1909).

Thomas H. Olds, President; R. I. Meeker, Secretary-Treasurer, 4100 Zenobia Street, Denver, Colo.

Atlanta Section (Constitution Approved by Board, 1912).

William C. Spiker, President; Frederick H. McDonald, Secretary-Treasurer, 1530 Healy Building, Atlanta, Ga.

Baltimore Section (Constitution Approved by Board, 1914).

Ezra B. Whitman, President; George S. Robertson, Sr., Secretary-Treasurer, 1628 Linden Avenue, Baltimore, Md.

Buffalo Section (Constitution Approved by Board, 1921).

Walter McCulloh, President; John H. Feigel, Secretary-Treasurer, 492 Minnesota Ave., Buffalo, N. Y.

Central Ohio Section (Constitution Approved by Board, 1921).

Frank W. Jennings, President; H. F. Schryver, Secretary, 405 New York Central Building, Columbus, Ohio.

Cincinnati Section (Constitution Approved by Board, 1920).

Edgar Dow Gilman, President; Alphonse M. Westenhoff, Secretary, 709 Gwynne Bldg., Cincinnati, Ohio.

Cleveland Section (Constitution Approved by Board, 1915).

A. V. Ruggles, President; George H. Tinker, Secretary-Treasurer, 516 Columbia Building, Cleveland, Ohio.

Connecticut Section (Constitution Approved by Board, 1919).

Harold W. Griswold, President; Clarence M. Blair, Secretary-Treasurer, 785 Edgewood Avenue, New Haven, Conn.

Dayton Section (Constitution Approved by Board, 1922).

Charles H. Paul, President; K. C. Grant, Secretary-Treasurer, Winters Bank Building, Dayton, Ohio.

Detroit Section (Constitution Approved by Board, 1916).

H. H. Esselstyn, President; Alex. Linn Trout, Secretary-Treasurer, 110 North Ingalls Street, Ann Arbor, Mich.

District of Columbia Section (Constitution Approved by Board, 1916).

Gratz B. Strickler, President; James H. Van Wagenen, Secretary-Treasurer, 2001 Sixteenth Street, N. W., Washington, D. C.

Duluth Section (Constitution Approved by Board, 1917).

William H. Hoyt, President; Walter G. Zimmermann, Secretary, 203 Wolvin Building, Duluth, Minn.

Illinois Section (Constitution Approved by Board, 1916).

A. J. Hammond, President; W. D. Gerber, Secretary-Treasurer, 913 Chamber of Commerce, Chicago, Ill.

Iowa Section (Constitution Approved by Board, 1920).

J. H. Dunlap, President; R. W. Crum, Secretary, Care, Iowa State Highway Commission, Ames, Iowa.

Kansas City (Mo.) Section (Constitution Approved by Board, 1921).

John V. Hanna, President; Henry C. Tammen, Secretary-Treasurer, 1012 Baltimore Avenue, Kansas City, Mo.

Kansas Section (Constitution Approved by Board, 1920).

L. E. Conrad, President; F. W. Epps, Secretary-Treasurer, State Highway Comm., Topeka, Kans.

Lehigh Valley Section (Constitution Approved by Board, 1922).

George H. Blakeley, President; M. O. Fuller, Secretary-Treasurer, 732 Avenue H, Bethlehem, Pa.

Los Angeles Section (Constitution Approved by Board, 1913).

Ralph J. Reed, President; Floyd G. Dessery, Secretary, 618 Central Building, Los Angeles, Calif.

Louisiana Section (Constitution Approved by Board, 1914).

Donald Derickson, President; F. A. Muth, Secretary, 224 Custom House Building, New Orleans, La.

Nashville Section (Constitution Approved by Board, 1921).

B. H. Klyce, President; L. C. Anderson, Secretary-Treasurer, Bridge Building, Nashville, Tenn.

Nebraska Section (Constitution Approved by Board, 1917).

William Grant, President; Homer V. Knouse, Secretary-Treasurer, 200 City Hall, Omaha, Nebr.

New York Section (Constitution Approved by Board, 1920).

J. Vipond Davies, President; Harold M. Lewis, Secretary, 130 East 22d Street, New York City.

Northeastern Section (Constitution Approved by Board, 1921).

Frank B. Sanborn, Chairman; Charles W. Banks, Secretary, 715 Tremont Temple, Boston, Mass.

Northwestern Section (Constitution Approved by Board, 1914).

W. T. Walker, President; Paul C. Gauger, Secretary, 300 Endicott Building, St. Paul, Minn.

Oklahoma Section (Constitution Approved by Board, 1920).

Max L. Cunningham, President; R. E. Brownell, Secretary-Treasurer, 402 First National Bank Building, Oklahoma, Okla.

Philadelphia Section (Constitution Approved by Board, 1913).

William Easby, Jr., President; Charles H. Stevens, Secretary-Treasurer, 5918 North Park Avenue, Philadelphia, Pa.

Pittsburgh Section (Constitution Approved by Board, 1918).

J. N. Chester, President; Nathan Schein, Secretary-Treasurer, 1510 Carson Street, Pittsburgh, Pa.

Portland (Ore.) Section (Constitution Approved by Board, 1913).

F. M. Randlett, President; C. P. Keyser, Secretary, 318 City Hall, Portland, Ore.

Providence (R. I.) Section (Constitution Approved by Board, 1920).

Sydney Wilmot, Chairman; Robert L. Bowen, Secretary-Treasurer, 26 Sycamore Street, Providence, R. I.

St. Louis Section (Constitution Approved by Board, 1914).

E. B. Fay, President; William C. E. Becker, Secretary-Treasurer, 426 City Hall, St. Louis, Mo.

San Diego Section (Constitution Approved by Board, 1915).

P. R. Watson, President; J. Y. Jewett, Secretary-Treasurer, Administration Building, Balboa Park, San Diego, Calif.

Seattle Section (Constitution Approved by Board, 1913).

F. F. Sinks, President; Frank H. Fowler, Secretary-Treasurer, 1319 L. C. Smith Building, Seattle, Wash.

Spokane Section (Constitution Approved by Board, 1914).

C. A. Burnette, President; Charles E. Davis, Secretary-Treasurer, 401 City Hall, Spokane, Wash.

Texas Section (Constitution Approved by Board, 1913).

E. B. Cushing, President; E. N. Noyes, Secretary, 1107 Dallas County Bank Building, Dallas, Tex.

Toledo Section (Constitution Approved by Board, 1922).

M. J. Riggs, President; George N. Schoonmaker, Secretary-Treasurer, High-Pressure Fire Service Station, Cherry and Water Streets, Toledo, Ohio.

Utah Section (Constitution Approved by Board, 1916).

B. W. Matteson, President; H. S. Kleinschmidt, Secretary-Treasurer, 222 Felt Building, Salt Lake City, Utah.

Virginia Section (Constitution Approved by Board, 1922).

J. C. Carpenter, President; James F. MacTier, Secretary-Treasurer, 1312 Maple Avenue, Roanoke, Va.

STUDENT CHAPTERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS *

Stanford University.

R. I. Hill, President; John H. Colton, Corresponding Secretary, Box 121, Stanford, Calif.

* By a recent ruling of the Board of Direction, the minimum membership of a Student Chapter has been fixed at 12 instead of 20.

Alabama Polytechnic Institute.

R. O. Davis, President; A. R. Harvey, Jr., Secretary-Treasurer, Box 661, Auburn, Ala.

Braune Civil Engineering Society (University of Cincinnati).

John W. Guilday, President; J. G. Appleton, Secretary, University of Cincinnati, Cincinnati, Ohio.

Bucknell University.

Ralph F. Hartz, President; Donald A. Davis, Secretary, Bucknell University, Lewisburg, Pa.

California Institute of Technology.

W. M. Taggart, President; Douglas A. Stromsoe, Secretary, California Institute of Technology, Pasadena, Calif.

Carnegie Institute of Technology.

H. T. Ward, President; J. K. Elliott, Secretary, Carnegie Institute of Technology, Pittsburgh, Pa.

Clemson Agricultural and Mechanical College of South Carolina.

J. H. Baumann, President; W. J. Stribling, Secretary, Clemson Agricultural and Mechanical College of South Carolina, Clemson College, S. C.

Cornell University.

Felix Spurney, President; Matthew J. Grogan, Secretary, Lincoln Hall, Cornell University, Ithaca, N. Y.

Drexel Institute.

W. J. Carroll, Chairman; Paul J. Tritschler, Secretary-Treasurer, Drexel Institute, Philadelphia, Pa.

Georgia School of Technology.

F. H. Harrison, President; C. M. Kennedy, Jr., Secretary, 91 West North Avenue, Atlanta, Ga.

Iowa State College.

Raymond L. Whannel, President; C. La Verne Day, Secretary, Iowa State College, Ames, Iowa.

Johns Hopkins University.

W. A. Randall, President; I. M. Zeskind, Secretary, Johns Hopkins University, Baltimore, Md.

Lafayette College.

Douglas M. Brown, President; Ivan C. Blickenstaff, Secretary, Lafayette College, Easton, Pa.

Lehigh University.

John N. Marshall, President; George R. Swinton, Lehigh University, Bethlehem, Pa.

Massachusetts Institute of Technology.

George Eric Barnes, President; Ralph Rutherford Dresel, Secretary, 53 Brook Street, Brookline, Mass.

Montana State College.

Merrill J. Alquist, President; Emmett Moore, Secretary, 921 South Third Avenue, Bozeman, Mont.

New York University.

George H. Martin, President; Abram J. Jacobs, Secretary, 302 Gould Hall, New York University, New York City.

North Carolina State College of Agriculture and Engineering.

H. T. Ivey, Secretary, State College Station, Raleigh, N. C.

Norwich University.

J. H. Kane, President; Allen J. Hamilton, Secretary, Norwich University, Northfield, Vt.

Ohio State University.

O. W. Merrell, President; R. G. Glass, Secretary, 1653 Summit Street, Columbus, Ohio.

Oregon State Agricultural College.

Richard D. Slater, President; Wilbur H. Welch, Secretary, Oregon State Agricultural College, Corvallis, Ore.

Pennsylvania State College.

Arthur H. McFadden, President; Ralph R. Dobelbower, Secretary, 564 Main Building, Pennsylvania State College, State College, Pa.

Polytechnic Institute of Brooklyn.

W. C. Hanning, President; S. Lordi, Secretary, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.

Purdue University.

R. O. Edwards, President; W. C. Mason, Secretary-Treasurer, Purdue University, West Lafayette, Ind.

Rensselaer Polytechnic Institute.

R. T. Carlson, President; G. C. Stephens, Secretary, 3 Walnut Grove Place, Troy, N. Y.

Rose Polytechnic Institute.

Robert Cash, President; F. Ray Martin, Secretary-Treasurer, Rose Polytechnic Institute, Terre Haute, Ind.

Rutgers College.

L. C. Kuhl, President; A. C. Ely, Secretary, 105 Winants Hall, Rutgers College, New Brunswick, N. J.

Stadia Club (University of Oklahoma).

Edward W. Mears, Secretary, University of Oklahoma, Norman, Okla.

State University of Iowa.

James Fred Phillips, President; Louis E. Baggs, Secretary, State University of Iowa, Iowa City, Iowa.

Swarthmore College.

Frank Lemke, President; H. Chandlee Turner, Jr., Secretary, Swarthmore College, Swarthmore, Pa.

Syracuse University.

Arthur V. Dollard, Secretary, College of Applied Science, Syracuse University, Syracuse, N. Y.

University of California.

E. F. Sutherland, President; H. E. Hedger, Secretary, University of California, Berkeley, Calif.

University of Colorado.

Glen L. Merar, President; F. K. Whiteside, Secretary, 1205 Thirteenth Street, Boulder, Colo.

University of Illinois.

R. H. Cooke, President; L. G. Straub, Secretary, University of Illinois, Urbana, Ill.

University of Kansas.

W. W. Hoagland, President; Waldo G. Bowman, Secretary, 1106 Ohio Street, Lawrence, Kans.

University of Kentucky.

H. J. Beam, President; H. E. Glenn, Secretary-Treasurer, 348 Harrison Avenue, Lexington, Ky.

University of Maine.

Ian M. Rusk, President; Clarence B. Gould, Secretary, Sigma Phi Sigma House, University of Maine, Orono, Me.

University of Minnesota.

C. L. Swanson, President, 1716 Tyler Street, N. E., Minneapolis, Minn.

University of Missouri.

W. K. Merridith, President; Charles Ogle, Secretary, University of Missouri, Columbia, Mo.

University of Nebraska.

J. E. Applegate, President; W. H. Mengel, Secretary, University of Nebraska, Lincoln, Nebr.

University of Pennsylvania.

Charles W. Foppert, President; Fred Welchy, Secretary, University of Pennsylvania, Philadelphia, Pa.

University of Pittsburgh.

L. W. Fletcher, President; J. M. Daniels, Secretary, University of Pittsburgh, Pittsburgh, Pa.

University of Texas.

Frank Cannon, President; Claude Riney, Secretary, 1908 Wichita Street, Austin, Tex.

University of Virginia.

T. B. Kiener, Secretary, University of Virginia, University, Va.

University of Washington.

Alfred Jensen, President; H. L. Worthington, Secretary-Treasurer, 5011 Seventeenth Avenue, N. E., Seattle, Wash.

University of Wisconsin.

K. Zander, President; E. K. Loverud, Secretary-Treasurer, University of Wisconsin, Madison, Wis.

Virginia Military Institute.

Benjamin F. Parrott, President; R. G. Hunt, Secretary-Treasurer, Virginia Military Institute, Lexington, Va.

Virginia Polytechnic Institute.

W. S. Miles, President; J. Byron Herring, Secretary, Virginia Polytechnic Institute, Blacksburg, Va.

Washington University Collimation Club.

Clarence H. Miller, President; Roger C. Rowse, Secretary, 5650 Bartmer Avenue, St. Louis, Mo.

West Virginia University.

Rupert J. Snooks, President; Albert L. Kelley, Secretary-Treasurer, 660 High Street, Morgantown, W. Va.

William Cain Civil Engineering Society (University of North Carolina).

H. G. Baity, President; L. I. Lassiter, Secretary, University of North Carolina, Chapel Hill, N. C.

Worcester Polytechnic Institute.

Carl F. Meyer, President; Albert P. Haydon, Secretary, Worcester Polytechnic Institute, Worcester, Mass.

Yale University.

Harry W. Alexander, President; William H. Meyer, Secretary, Winchester Hall, Yale University, New Haven, Conn.

NEW BOOKS*

(From May 1st to June 30th, 1922)

The statements made in these notices are taken from the books themselves, and this Society is not responsible for them.

DONATIONS TO ENGINEERING SOCIETIES LIBRARY

PRACTICAL WIRELESS TELEGRAPHY.

By Elmer E. Bucher. Revised Edition. N. Y. and Lond., Wireless Press, 1921. 336 pp., illus., diagrams, 9 x 6 in., cloth. $2.25.

The author endeavors to give non-technical students and practical telegraphers an understanding of the working of modern commercial apparatus. Stress is laid on the construction of apparatus and the methods of manipulating it, without attempting a complete account of the scientific principles underlying it.

DIRECTIVE WIRELESS TELEGRAPHY.

By L. H. Walter. (Pitman's Technical Primers.) Lond. and N. Y., Sir Isaac Pitman & Sons, Ltd., 1921. 124 pp., illus., diagrams, 6 x 4 in., cloth. 85 cents.

A short connected account of the principles of the method of wireless direction finding, together with the essentials of directive wireless telegraphy on which it is based. Although small, the volume aims at giving an outline of all the information available. It is intended for those who are about to use the directive finder and for those who are interested in directive wireless telegraphy. A bibliography is given as a guide for those who desire to study the theory fully.

ELEMENTS OF RADIO TELEPHONY.

By William C. Ballard. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. 132 pp., illus., plates, diagrams, 7 x 5 in., fabrikoid. $1.50.

This book gives a simple discussion of what happens when messages are sent and received by radio, of the apparatus required to produce these effects, and of its method of operation. It also gives practical unbiased information for the experimenter who wishes to learn what apparatus is necessary to produce certain results. Being intended for non-technical readers, the use of mathematics is avoided almost entirely.

TESTING OF TRANSFORMERS AND ALTERNATING-CURRENT MACHINES.

By Charles F. Smith. (Pitman's Technical Primer Series.) Lond. and N. Y., Sir Isaac Pitman & Sons, Ltd., 1922. 91 pp., illus., 7 x 4 in., cloth. 85 cents.

The author gives in compact form an outline of the main principles underlying practice in making efficiency and output tests of alternating transformers, generators, and motors for commercial purposes.

PAPERS ON CURRENT TRANSFORMERS.

By H. W. Price and C. Kent Duff. (University of Toronto School of Engineering Research, Bulletin No. 2, Section No. 4.) University of Toronto Press, 1921. 65 pp., illus., diagrams, 9 x 6 in. (Free.)

The five papers contained in this *Bulletin* are the electrical studies for the year 1921 at the University of Toronto School of Engineering Research. They have to do with investigations of the effects of magnetic leakage, a method of measuring ratio and phase angle, through-type portable transformers, and with minimizing errors by means of shunts. In view of the present interest in the design of current transformers, these papers will be of value to designers. Little is available in print on the subjects here discussed.

HIGH-VOLTAGE POWER TRANSFORMERS.

By William T. Taylor. (Pitman's Technical Primer Series.) Lond. and N. Y., Sir Isaac Pitman & Sons, Ltd., 1922. 117 pp., illus., diagrams, 6 x 4 in., cloth. 85 cents.

The author has given a general practical survey of the characteristics, construction, installation, operation, and troubles of modern high-voltage power transformers. The book

* Unless otherwise specified, books in this list have been donated by the publishers.

is intended for station operators and general electric engineers and therefore does not treat problems of fundamental design, details of construction, and similar topics which chiefly concern manufacturers.

ELECTRICAL ENGINEERING TESTING.

By G. D. Aspinall Parr. (Directly-Useful Technical Series.) Fourth Edition. N. Y., E. P. Dutton & Co., 1922. 691 pp., illus., diagrams, 9 x 6 in., cloth. $8.00.

This is a systematic course of instruction in testing alternating and continuous-current machinery and equipment, for use by students and by engineers engaged in practical work. The present edition has been considerably enlarged, chiefly by adding new tests, and re-arranged so that tests of a like nature are together.

ELECTRIC POWER SYSTEMS.

By William T. Taylor. (Pitman's Technical Primer Series.) Lond. and N. Y., Sir Isaac Pitman & Sons, Ltd., 1922. 107 pp., 6 x 4 in., cloth. 85 cents.

This little book is an extremely brief introductory statement of the main technical facts and principles governing modern practice in the larger electric power systems. General circuit conditions are considered; the most important methods and problems in generation, transmission, and distribution practice are explained; and special attention is paid to system operation, to the various "system factors" used, and to the importance of keeping reliable operating records.

DIE DRAHTLOSE TELEGRAPHIE UND TELEPHONIE.

Von P. Lertes. (Wissenschaftliche Forschungsberichte.) Dresden und Leipzig, Theodor Steinkopff, 1922. 152 pp., diagrams, 9 x 6 in., paper. 78 marks.

The need for concise summaries of current literature on scientific subjects is felt by all investigators, and particularly at present by German scientists, most of whom were unable, during the war, to keep in touch with developments in their respective fields of study. The present volume is one of a series prepared to meet this need, by providing reviews of the advances after 1914 along various lines, prepared by competent students of each subject. This review of advances in radio communication covers theory and the various parts of sending and receiving apparatus. The literature from 1914 to 1921 has been examined. Bibliographies are given for each section.

DIE ELEKTROTECHNIK UND DIE ELEKTROMOTORISCHEN ANTRIEBE.

Von Wilhelm Lehmann. Berlin, Julius Springer, 1922. 451 pp., illus., diagrams, 9 x 6 in., cloth. $2.35.

The problems that confront the greater number of electrical engineers to-day are not, the author believes, connected with the construction of electrical machinery nor the generation of electricity, but with the industrial use of electrical energy. His book, therefore, is chiefly devoted to discussing types of electrical machines and their suitability for various purposes. Direct-current, alternating-current, and induction generators and motors, transformers, the transmission and distribution of electric power, and its use for lighting, and power purposes are considered. One section is devoted to electric driving in the more important industries.

RULES FOR THE CONSTRUCTION AND CLASSIFICATION OF WOOD SHIPS.

Published by the American Bureau of Shipping, N. Y., 1921. 394 pp., tab., 8 x 6 in., paper.

This work sets forth in detail the rules adopted by the Bureau to govern the construction of wood vessels intended for ocean service in all parts of the world, and also its rules for classification and surveys. A list of the surveyors of the Bureau, domestic and foreign, is included.

MODERN GAS TRACTOR.

By Victor W. Pagé. Fourth Edition, Revised and Enlarged. N. Y., The Norman W. Henley Publishing Co., 1922. 590 pp., illus., diagrams, 7 x 5 in., cloth. $3.00.

The object of the author has been to present the principles of design in a simple manner and to show how these principles have been followed in various types of construction, so that the advantages of the various methods may be intelligently analyzed by the average farmer and mechanic. The book is intended to assist in the selection of the best mechanism for individual requirements. Chapters on maintenance and repair are included.

STEAM POWER PLANT AUXILIARIES AND ACCESSORIES.

Terrell Croft, Editor. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. 447 pp., diagrams, illus., 8 x 6 in., cloth. $3.00.

This book is intended to give data that will assist the power plant engineer to select proper auxiliary equipment and install, operate and maintain it so that preventable losses will be kept as low as possible and power will be generated at the least cost. The subjects

treated include pumps, boiler-feeding apparatus, feed-water heaters, economizers, condensers, cooling ponds and towers, steam piping, steam separators, and steam traps. The treatment is simple, non-mathematical, and descriptive.

MODERN PUMPING AND HYDRAULIC MACHINERY.

By Edward Butler. Second Edition, Revised. Lond., Charles Griffin and Co., Ltd., 1922. 475 pp., illus., diagrams, 9 x 6 in., cloth. $9.00. (Gift of J. B. Lippincott & Co.)

The author has attempted to present in a clear, concise form information especially useful to engineers, designers, and others engaged in the construction or application of pumping and hydraulic machinery to various purposes. The whole range of pumping appliances, as well as the machinery used in hydraulic transmission and power generation, is treated systematically and exhaustively.

MODERN PRACTICE IN HEAT ENGINES.

By Telford Petrie. Lond. and N. Y., Longmans, Green and Co., 1922. 264 pp., illus., pl., diagrams, 9 x 6 in., cloth. $5.00.

The author has given a concise treatment of the subject of power from heat engines, which attempts to show how far theory may be applied to the design of modern types. The book is divided into three sections, steam, prime movers, and internal combustion engines. Each section contains chapters descriptive of late types and on the principles of design. The results of a number of reliable modern tests are given.

FUEL AND REFRACTORY MATERIALS.

By A. Humboldt Sexton. New Edition, Revised by W. B. Davidson. N. Y., D. Van Nostrand Co., 1921. 382 pp., illus., diagrams, tab., 9 x 6 in., cloth. $4.00.

No important alterations have been made in the original text of this well-known work, but minor corrections have been made throughout. The chapters on liquid and gaseous fuels have been modified and enlarged, and the chapter on by-products has been rewritten. The chapters on fuel testing and refractories have been modernized and enlarged. The book discusses the important industrial fuels, metallurgical furnaces, pyrometry, calorimetry, fuel testing, and the refractory materials used for furnaces and crucibles.

METAL CUTTING TOOLS.

By A. L. De Leeuw. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. 328 pp., illus., diagrams, 9 x 6 in., cloth. $3.00.

The book is intended to bring before the reader the principles that must be applied in selecting, designing, maintaining, and, especially, in using metal-cutting tools. It is intended for engineers, foremen, time-setters, and mechanics. Slight use is made of mathematics, and mathematical knowledge is not essential for an understanding of most of the subjects considered.

LAPPING AND POLISHING.

By Edward K. Hammond. (*Machinery's* Blue Books.) N. Y., Industrial Press; Lond., Machinery Publishing Co., Ltd., 1921. 60 pp., illus., 8 x 6 in., paper. 50 cents.

This pamphlet reviews modern practice in lapping operations, in the light of the improvements developed during recent years, and also gives an account of current method for polishing tools and parts.

FORD CAR, TRUCK, AND TRACTOR REPAIR.

By Alfred A. Good. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. 229 pp., illus., 7 x 5 in., fabrikoid. $2.00.

This is a concise text by the former Director of the Service School of the Ford Motor Company. It is intended to give the mechanic a complete account of the mechanical principles underlying the operation of Ford automobiles and tractors, which will enable him to diagnose troubles correctly and repair them properly.

DYNAMICS OF THE AEROPLANE.

By René Devillers. Translated by W. J. Walker. New Impression. Lond., E. & F. N. Spon, Ltd., 1922. 302 pp., 9 x 6 in., cloth. 15 shillings.

The author's investigation is concerned with the effects on the equilibrium of an airplane of the movement of its center of gravity and that about its center of gravity; or, in other words, of the different paths of flight and of its stability. The theoretical considerations are considered and the mathematical formulas evolved, but the principal aim has been to condense experimental results into simple technical form which the engineer can put to immediate use. All current formulas have been reduced to nomographic form, the book being, according to the translator, the first in English to adopt that method throughout.

TRAITÉ PRATIQUE DE NAVIGATION AÉRIENNE.

Par A. B. Duval, L. Hébrard. Paris, Gauthier-Villars et Cie., 1922. 60 pp., diagrams, 11 x 9 in., paper.

The subjects covered in this elementary textbook are: The general rules of aerial navigation, the compass, navigation by dead-reckoning, navigation by observations, navigating instruments and the practice of navigation. The presentation is adapted to the needs of the commercial navigator, interested solely in traveling from one terminus to the other by the shortest, easiest way, rather than to those engaged in sport or touring.

METALLURGY OF IRON AND STEEL.

Based Mainly on the Work of Sir Robert A. Hadfield. (Pitman's Technical Primer Series.) Lond. and N. Y., Sir Isaac Pitman & Sons, Ltd., 1922. 122 pp., illus., tab., 7 x 4 in., cloth. 85 cents.

This is a brief outline of the discoveries and developments on which are based modern practice in the metallurgy of iron and steel. Stress is laid on the importance of conservation and the assistance rendered in this direction by progress in metallurgy. The book is based on Sir Robert Hadfield's published papers, of which a list is given.

DETERMINATION OF SULFUR IN IRON AND STEEL;

With a Bibliography, 1797-1920. By H. B. Pulsifer. Easton, Pa., Chemical Publishing Co., 1922. 160 pp., illus., 9 x 6 in., cloth. $2.50.

Although the determination of sulphur is one of the fundamental control analyses in ascertaining the quality of iron and steel, and is in regular daily use in all laboratories, there is still a lack of suitable accuracy and an unflattering absence of agreement between analysts, which calls for study of the methods in use. The present book is a review of present knowledge concerning the sulphides that occur in iron and steel, the methods of analysis, the results obtained with them, and the precision of these results. It is intended to provide a basis for research. The bibliography (pp. 53-155) covers the literature from the beginnings of wet analytical chemistry and is fully annotated.

ON THE ELECTRO-DEPOSITION OF IRON.

By W. E. Hughes. (Dept. of Scientific and Industrial Research, *Bulletin No. 6.*) Lond., H. M. Stationery Office, 1922. 50 pp., pl., paper. 6 shillings 8½ pence.

The author reports the results of an extensive laboratory investigation of the structure of electro-deposited iron, together with his conclusions regarding the influence of various factors on this structure. The effects of temperature, current density, and movement of the cathode or electrolyte are given special attention. The conclusion is reached that the general theories entertained in regard to the crystallization of other substances hold also for deposited metal and that the dominant factor governing structure is concentration.

IRON AND ITS COMPOUNDS.

By J. Newton Friend. (Text Book of Inorganic Chemistry, Vol. 9, Pt. 2.) Lond., Charles Griffin and Co., Ltd., 1921. 265 pp., 9 x 6 in., cloth. 18 shillings.

The present book is the first of two treating of the subject of the chemistry of iron, and deals with the chemistry of iron and its compounds. The second volume will be devoted to the metallurgical chemistry of iron. Like the other volumes of this treatise, the book is intended, without being absolutely exhaustive, to give a concise, suggestive account of its topic, and to furnish numerous references to the leading works and memoirs on it. The result is a concise, modern statement of our knowledge of the chemistry of iron, well arranged for reference use.

STEEL FOUNDRY.

By John Howe Hall. Second Edition. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. 334 pp., illus., diagrams, tab., 9 x 6 in., cloth. $4.00.

Mr. Hall's object has been to set forth the metallurgy of the steel foundry from the point of view of the engineer interested in prescribing the cheapest means of producing objects of sufficient excellence for the purposes for which they are intended. His book considers the classes of steel castings in demand to-day and their characteristics from a manufacturing point of view; the types of steel making processes in use and their characteristics that govern the selection of one or another for making the sort of castings desired; and shop procedure in the light of its influence on quality and cost. The revision has introduced new data on electric furnace practice, on moulding sands, heat treatment, and other phases of foundry practice.

ANALYSIS OF NON-FERROUS ALLOYS.

By Fred Ibbotson and Leslie Aitchison. Second Edition. Lond. and N. Y., Longmans, Green and Co., 1922. 246 pp., diagrams, tab., 9 x 6 in., cloth. $4.00.

This book contains a collection of methods for the analysis of non-ferrous alloys recommended by the authors as combining accuracy with speed and convenience in the highest degree. The methods are especially suited to the needs of works chemists. This

edition includes additional methods for light aluminium, copper-nickel and chromium-nickel alloys, and the special elements added to copper-zinc and copper-tin alloys, such as iron and manganese.

CYANIDING GOLD AND SILVER ORES.

By H. Forbes Julian and Edgar Smart. Third Edition, Revised and Enlarged. Lond., Charles Griffin and Co., Ltd.; Phila., J. B. Lippincott Co., 1921. 417 pp., diagrams, tab., 9 x 6 in., cloth. $12.50.

The second edition of this well-known treatise appeared in 1907. Work on the present edition was begun in 1914; it was interrupted by the death of Mr. Smart and by the World War, but it was finally completed by A. W. Allen. Much new material dealing with recent modifications in the theory and operation has been added and the chapters have been re-arranged to secure greater uniformity. The principal additions are in connection with colloidity and absorption; the theory of gold precipitation on charcoal; milling in cyanide solution, flotation, and cyanidation; zinc-box practice; deoxodizing solutions; counter-current decantation; aluminium, sodium sulphide and charcoal precipitation; agitation, slime-settlement and filtration equipment.

NOTES ÉCONOMIQUES D'UN MÉTALLURGISTE.

By Camille Cavallier. Paris, Gauthier-Villars et Cie., 1921. 153 pp., 9 x 6 in., paper. 3 francs 50.

These brief economic discussions, by a French iron manufacturer, treat various present problems of French industry, particularly metallurgy. Such questions as the comparison between the foreign trade of France and Germany, the participation of manufacturers in National affairs and the relations of the heads of enterprises with capital and labor are treated, and the causes of and remedies for the present economic crisis are discussed in the light of long experience in industry.

LES PROGRES DE LA MÉTALLURGIE DU CUIVRE.

Par Auguste Conduché. (Encyclopédie Léauté.) Paris, Masson et Cie.; Gauthier-Villars et Cie., 1922. 254 pp., illus., 8 x 5 in., paper. 14 francs.

Considerable progress has been made in recent years in the metallurgy of copper, due in part to the technical improvement of machinery and plants, but still more to scientific investigation and to the careful utilization of the chemical reactions that occur. This book is a concise account of this progress. It provides a statement of present knowledge of the properties of copper, the effects of impurities, its alloys, and the methods of smelting and refining, with careful attention to scientific principles, and to the economic factors. It also presents a typical example of the value of systematic research and scientific methods for the development of an industry.

COAL MINING COSTS.

By A. T. Shurick. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. 515 pp., diagrams, tab., 9 x 6 in., cloth. $5.00.

Although books on costs exist for all the other important branches, this is the first to treat of coal mining costs. The author has restricted his inquiry to underground costs, covering mining, shaft-sinking, haulage, timbering, and various miscellaneous items. The treatment has been made as thorough and specific as possible. By giving the date when each piece of work was done and including a table showing all the wage scales in the Central Competitive District since 1898, it has been made a simple matter to estimate the cost in terms of present wage scales.

COAL MANUAL FOR SALESMEN, BUYERS, AND USERS.

By F. R. Wadleigh. Cincinnati, Ohio, National Coal Mining News, 1921. 184 pp., 6 x 5 in., cloth. $2.50.

A book of pocket size intended to give accurate elementary knowledge regarding the origin, structure, chemistry, and uses of coal. It is intended for salesmen and users of coal who wish information on methods of purchasing, transporting, and testing coal and coke, on the requirements of various users, and on proper methods of using fuel.

MINING HAND BOOK, CANADA, 1922.

Compiled by R. E. Hore. Toronto, Investor's Mining Hand Book Co. 128 pp., 6 x 4 in., paper. $1.00.

This pamphlet comprises a brief compendium of statistics relating to mineral production, prices of mining stocks, dividends, etc., and a list of the mining companies of Canada. The situation, capitalization, and officers are given.

COAL.

By Elwood S. Moore. N. Y., John Wiley & Sons, Inc., Lond., Chapman & Hall, Ltd., 1922. 462 pp., illus., maps, tab., 9 x 6 in., cloth. $5.00.

The book was prepared to satisfy the demand for a convenient modern summary of the voluminous scattered literature on coal. It covers quite fully such topics as the properties,

origin, uses, and general distribution of coal, while discussing only in a more general way such subjects as mining machinery and the details of distribution and character of local deposits.

PETROLEUM REFINING.

By Andrew Campbell. Second Edition. Lond., Charles Griffin and Co., Ltd.; Phila., J. B. Lippincott Co., 1922. 297 pp., illus., diagrams, tab., 9 x 6 in., cloth. $8.50.

This is the only work extant devoted solely to petroleum refining. It is confined to ordinary methods of refining, both in laboratory and works practice, as they have come within the purview of the author, whose experience has been chiefly gained with the Burmah Oil Company, Limited. An extensive bibliography is included. This edition is identical with the first, except for the correction of errors.

ANNALS OF THE AMERICAN ACADEMY

Of Political and Social Science, May, 1922. 315 pp., 9 x 6 in., paper. $1.00.

The American Academy of Political and Social Science has done a great service to all the professions by bringing together for the first time in one collection the concepts of what constitutes the attainment of the ideals of a profession, in distinction from those of a vocation. Contents: The Significance of the Ethical Codes for the Professions; The Ethical Codes of Lawyers; The Ethics of the Medical Profession; The Ethical Codes of the Engineers: The Ethics of the Architects; Ethical Standards for Teachers, Librarians, Ministers, and Social Workers; Ethical Standards for Journalists; The Ethical Code of Accountants; Ethics in Business; Supplement: Modern China and Her Present Day Problems.

PROTEINS AND THE THEORY OF COLLOIDAL BEHAVIOR.

By Jacques Loeb. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. 292 pp., tab., charts, 9 x 6 in., cloth. $3.00.

Colloid chemistry has been developed on the assumption that the ultimate unit in colloidal solutions is not the isolated molecule or ion, but an aggregate of molecules or ions. Since it seemed improbable that such aggregates could combine in stoichiometrical proportions with acid, alkalies, or salts, the conclusion was drawn that electrolytes were absorbed on the surface of colloidal particles according to a purely empirical formula. Dr. Loeb's investigations have shown that this last conclusion is based on a methodical error, that proteins combine with acids and alkalies according to the stoichiometrical laws of chemistry and that the chemistry of proteins does not differ from the chemistry of crystalloids. This book furnishes the proof of his conclusions and outlines a mathematical and quantitative theory of colloid behavior.

INORGANIC CHEMISTRY.

By T. Martin Lowry. Lond., Macmillan and Co., Ltd., 1922. 943 pp., illus., diagrams, 9 x 6 in., cloth. $9.00. (Gift of The Macmillan Co., N. Y.)

This is a large textbook which is intended to bridge the gap between the elementary class book and the larger reference treatises. The author presents the subject in a modern way, giving full weight to the influence of physical chemistry on the subject. The earlier historical and introductory chapters treat of states of matter, salts, acids, alkalies, combustion, chemical combination, the atomic theory, crystallization, etc. The systematic part of the book describes the elements and their compounds. Equilibrium diagrams have been used freely and important industrial operations described.

CHEMISTRY OF THE NON-BENZENOID HYDRO-CARBONS.

By Benjamin T. Brooks. N. Y., Chemical Catalog Co., Inc., 1922. 612 pp., 9 x 6 in., cloth. $7.00.

The compounds considered in this book include such industrially important substances as petroleum, rubber, turpentine, camphor and the essential oils. Dr. Brooks presents a systematic description of the chemistry of the non-benzenoid hydrocarbons, in which is included both matter of only theoretical interest and descriptions of industrial processes. The volume is a useful review of a field usually given a secondary position in treatises on organic chemistry. Ample references to the previous literature are included.

DICTIONARY OF APPLIED CHEMISTRY.

Vol. 3. By Sir Edward Thorpe. Revised and Enlarged Edition. N. Y., Longmans, Green and Co., 1922. 735 pp., illus., 9 x 6 in., cloth. $20.00.

The third volume contains an important article, 98 pages long, on Explosives, by G. H. Perry; one on Glass, by W. E. S. Turner; on Water-Gas, by Alwyne Meade; and on Iron by Thomas Turner. Dr. William A. Bone contributes an article on Fuel, Dr. Arthur Harden one on Fermentation. The articles on Fire Extinction and Prevention, and on Air Gas and Oil Gas are by Vivian B. Lewes. Dr. Julius Lewkowitch is responsible for a number of articles on oils, fats, and waxes.

SOME PHYSICO-CHEMICAL THEMES.

By Alfred W. Stewart. Lond. and N. Y., Longmans, Green and Co., 1922. 419 pp., pl., diagrams, 9 x 6 in., cloth. $7.00.

This book is a volume of independent chapters, each giving a brief account of an interesting branch of physical chemistry. It is intended to bridge the gap between the textbook and the original literature on the subjects, it being the hope of the author that it will stimulate the student to seek further information in the original literature and lay a foundation sufficient to allow him to read the more recent researches with understanding. The selection of subjects has been guided by the interest of the author and his students. Those treated have a certain connected thread of interest, which is brought out by the arrangement.

LABORATORY EXERCISES IN INORGANIC CHEMISTRY.

By James F. Norris and Kenneth L. Mark. (International Chemical Series.) N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. 548 pp., 8 x 6 in., cloth. $2.00.

This volume contains, in addition to the experiments ordinarily found in such books, new experiments designed to illustrate the general principles that are being more and more emphasized in instruction in chemistry. Intended for college students who have had good training in chemistry in the high school.

CATALYTIC ACTION.

By K. George Falk. N. Y., Chemical Catalog Co., Inc., 1922. 172 pp., 9 x 6 in., cloth. $2.50.

This is a study of the group of chemical reactions known as catalytic actions, based on the general theory of chemical reactions developed by the author in another book. The object is to define as accurately as possible the group of catalytic reactions, to show their relations to other chemical reactions, and to find, if possible, general relations underlying the cause or mechanism of these reactions. Contents: General Views on Catalysis; Reaction Velocity and Catalysis; Theory of Catalytic Actions; Energy Relations; Recent Theories of Chemical Action; Enzyme Actions; A Chemical Interpretation of Life Processes; Contact Catalysis.

FLUIDITY AND PLASTICITY.

By Eugene C. Bingham. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. 440 pp., tab., diagrams, 8 x 6 in., cloth. $4.00.

Dr. Bingham's book is a careful study of the knowledge concerning the flow of gases, liquids, and solids, and of the theories that have been advanced by different investigators. Part 1 discusses viscometry and the viscometer. Part 2 treats of viscosity, fluidity, and plasticity, and includes chapters on lubrication and on further applications of the viscometric method. The author offers a theory of flow in general, the first to be published. An extensive bibliography is included.

ISOTOPES.

By F. W. Aston. Lond., Edward Arnold & Co., 1922. 152 pp., pl., diagrams, 9 x 6 in., cloth. $3.00. (Gift of Longmans, Green & Co.)

In clear, readable style, Dr. Aston gives an adequate exposition of the phenomena of isotopic elements. The book gives an exact account of the discovery of isotopes, of the methods used to detect them and of present theories in explanation of them. Particular attention is paid to the author's mass-spectrograph and the work done with it on various elements.

DICTIONARY OF APPLIED PHYSICS.

Vol. 1. Edited by Sir Richard Glazebrook. Lond., Macmillan and Co., Ltd., 1922. 1067 pp., illus., diagrams, 9 x 6 in., cloth. $15.00.

This is the first volume of an important work of reference in which will be summarized the present state of knowledge of physics as applied to matters of engineering and manufacturing. Each volume will cover one branch of the science and be practically complete within itself. In preparing the book, Sir Richard Glazebrook has had the help of many of the leading physicists, who have contributed articles on their specialties. The work will consist of five volumes. The present volume covers Mechanics, Engineering, and Heat. It contains extensive reviews on Steam and Internal Combustion Engines, Hydraulics, Calorimetry and Thermometry, Lubrication, Determination of Elastic Constants, Thermodynamics, Friction, Steam Turbines, Ship Resistance, Strength of Structures, and Dynamometers. Bibliographies are given.

DYES CLASSIFIED BY INTERMEDIATES.

By R. Norris Shreve, in Collaboration with W. N. Watson and A. R. Willis, N. Y., Chemical Catalog Co., Inc. 631 pp., 9 x 6 in., cloth. $10.00.

The contents of this book fall into two parts: First, an alphabetical list of intermediates with their data and dye tables; and second, an alphabetical index of dye names, by which any dye referred to may be found in the tables. Under each name in the list of intermediates are given its synonyms, structural formula, empirical formula, molecular weight, method of formation, statistics of manufacture, and dyes derived from it. The quantities of each dye manufactured or imported are given in most cases. The book will be of service to research chemists, manufacturers, and users of dyes, and merchants engaged in buying or selling dyes and intermediates.

MANUFACTURE OF PULP AND PAPER.

Vol. 3. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. Illus., diagrams, 9 x 6 in., cloth. $5.00.

This is the third volume of the course of instruction in pulp and paper manufacture prepared by the pulp and paper industry of North America for those actively engaged in the industry. Previous volumes have been devoted to the elementary scientific knowledge—physical, chemical, and mathematical—needed by the paper maker, the present volume takes up the actual manufacturing processes. It is, the editor announces, the first work in English dealing solely and comprehensively with wood pulp manufacture. The various sections have been prepared by specialists. They describe the properties of pulpwood, its preparation, the manufacture of mechanical, sulphite, soda, and sulphate pulps, and the treatment, refining, testing, and bleaching of pulp.

PRINCIPLES OF LEATHER MANUFACTURE.

By H. R. Procter. Second Edition. Lond., E. & F. N. Spon, Ltd., 1922. 688 pp., illus., 10 x 6 in., cloth. 32 shillings.

This treatise deals with the general scientific principles of the industry, without describing in detail its practical methods, although many practical points are discussed. The second edition, issued after an interval of eighteen years, has been thoroughly revised, so that the new points of view occasioned by the advances in physical and colloidal chemistry are covered. The volume is intended for chemists and practical tanners.

PRACTICAL TANNING.

By Allen Rogers. N. Y., Henry Carey Baird & Co., Inc., 1922. 699 pp., illus., port., 9 x 6 in., cloth. $10.00.

As Dr. Rogers has written for the practical tanner, his book gives prominence to the methods used for the actual production of leather, although the scientific principles on which these methods are based are also stated, in simple language. In addition to the common standard methods of tanning, a number of unusual processes are given, as well as descriptions of some of the substitutes for leather. The book is based on Flemming's "Practical Tanning", with the addition of the results of the author's personal experience.

THE TELESCOPE.

By Louis Bell. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. 287 pp., illus., diagrams, 9 x 6 in., cloth. $3.00.

This book is written for those who use telescopes for study or pleasure and desire more information about their construction and properties. It attempts neither exhaustive technicalities nor popular descriptions of great observatories and their work, but deals primarily with principles and their application to such instruments as are likely to come into the possession of students of the heavens. Much has been written of telescopes, first and last, but it is for the most part scattered and inaccessible to the ordinary reader, and it is many years since any book has dealt with the telescope itself, apart from the accounts of the marvels it discloses.

CLAY PRODUCTS CYCLOPEDIA.

First Annual Edition. Chic., Industrial Publications, Inc., 1922. 252 pp., illus., diagrams, 12 x 9 in., cloth. $3.00.

The first section of this publication consists of definitions of processes, materials, and equipment used in the clay industries. Section 2 describes the associations of clay workers and their activities. Section 3 is an index to the cyclopedia, classified by plant departments. Section 4 contains statistical data, specifications, tests, and engineering information. Section 5 consists of catalog descriptions of machinery. The book presents a large amount of up-to-date practical information in convenient form for quick reference.

BUILDING CONTRACTS.

By Edwin J. Evans. (Directly-Useful Technical Series.) N. Y., E. P. Dutton & Co., 1922. 304 pp., 9 x 6 in., cloth. $5.00.

A book on business management for contractors, dealing with the various matters that chiefly affect the administration of a contractor's business, and giving suggestions as to the best means of mobilizing and organizing the available forces for the financial and constructional success of the work. Adapted to conditions and practices of the building trade in England, but may be suggestive for similar work in the United States.

YOUNG MAN AND CIVIL ENGINEERING.

By George Fillmore Swain. (Vocational Series.) N. Y., Macmillan Co., 1922. 203 pp., 8 x 5 in., cloth. $2.00.

Dr. Swain writes in interesting fashion concerning the branches of civil engineering, the qualifications necessary for the civil engineer, his education, the characteristics of the profession and the outlook for the civil engineer. His book is well calculated to assist the young man in estimating his own fitness for the profession and to help him direct his education along proper channels.

THE GANTT CHART.

By Wallace Clark. N. Y., Ronald Press Co., 1922. 9 x 6 in., cloth. $2.50.

This book explains the principle of this chart, the method of making and reading it, and shows its application to machine, man, planning, load, and progress records. One chapter describes its use by the Shipping Board during the World War. It will enable those interested to apply this method of charting their records to their own activities.

TABLES CENTÉSIMALES POUR LE TRACÉ DES COURBES.

Par J. Bouchard. Paris, Gauthier-Villars et Cie., 1922. 201 pp., 10 x 5 in., paper. 15 francs.

These tables have been prepared to meet the needs of civil engineers and surveyors who are using instruments divided on the decimal system. They give the natural trigonometric fractions on the decimal system to six places of decimals, from zero to a right angle.

L'AZOTE.

Par Louis Hackspill. (Encyclopédie Léauté.) Paris, Masson et Cie.; Gauthier Villars et Cie., 1922. 271 pp., illus., 8 x 5 in., paper. 14 francs.

As a member of military commissions of chemical control in Germany, the author acquired an intimate knowledge of the nitrogen industry and had an opportunity to study thoroughly the commercial plants at first hand. His book deals with the different processes, giving the history of each and describing the reactions and apparatus used. The various processes are also compared critically from the economic point of view.

COURS DE MÉCANIQUE APPLIQUÉE.

By Marcel Lamotte. Paris, Gauthier-Villars et Cie., 1922. 282 pp., diagrams, 10 x 6 in., paper. 25 francs.

Professor Lamotte feels that most textbooks of applied mechanics require more extensive knowledge than the usual student possesses and are unnecessarily difficult. He has prepared this book, not to replace the more elaborate treatises on the subject, but to prepare the student for them, so that he may derive the most profit from their perusal. This is accomplished by presenting, in the simplest form possible, some of the questions that affect the applications of mechanics. He is less concerned in establishing general theories than in showing, by examples, how practical problems may be solved.

ELEKTRISCHE BEHANDLUNG VON GASEN.

Herausgegeben von Henri Silbermann. Leipzig, Dr. Max Jänecke, 1922. 348 pp., illus., diagrams, 8 x 6 in., paper. $3.20.

This work is a summary of information on the effect of electric discharges on gases, especially the atmosphere, as disclosed by an examination of the German patent records. The subjects discussed are the activation of oxygen (preparation of ozone), the separation of solid or liquid particles from gases (purification by dust and mist removal), and the double decomposition of reaction masses containing at least two elements (synthesis of nitric acid, ammonia, cyanogen, etc.). The book is a convenient record of the present state of these arts.

HYDRO-ELECTRIC INSTALLATIONS OF INDIA.

By Shiv Narayan. Poona, India, The Author, 1922. 302 pp., illus., 10 x 6 in., cloth. 9 rupees.

This book presents in popular form the principal facts concerning the hydro-electric plants and projects of India. It also explains the hydraulic and electrical principles involved, the general design and installation of plants and the economic factors to be considered. The work is intended to direct attention to the water-power resources of the country and to serve as a guide to engineers and capitalists interested in the utilization of them.

DESIGN AND CONSTRUCTION OF DAMS.

By Edward Wegmann. Seventh Edition. N. Y., John Wiley & Sons, Inc., 1922. 555 pp., pl., diagrams, 12 x 9 in., cloth. $10.00.

The changes in this edition consist chiefly of added matter, amounting to about fifty pages of text and five plates. A new chapter has been inserted on crest gates and siphon spillways, additional descriptions of recent dams are given, and the bibliography has been extended. A full description of the construction of the Kensico Dam is included and the movable dams of the New York State Barge Canal are described.

DIENST VOOR WATERKRACHT EN ELECTRICITEIT IN NEDERLANDSCH-INDIE.

Derde jaarverslag, 1920. Bandoeng, 1921. 71 pp., pl., maps, tab., 10 x 7 in., boards.

The Annual Report for 1920 of the Hydroelectric Service of the Government of the Dutch East Indies contains a brief account of its activities in examining and developing the water powers of Java, Sumatra, Celebes, and the smaller islands. Statistical tables, maps, and graphic charts give much detailed information, and the report is well illustrated by photographs.

THERMAL STRESSES IN CHILLED IRON CAR WHEELS.

By G. K. Burgess and R. W. Woodward. (Technologic Papers of the Bureau of Standards, No. 209.) Wash., Govt. Printing Office, 1922. 34 pp., pl., diagrams, 10 x 7 in., paper. 5 cents.

Describes a method for testing car wheels under conditions nearly like those encountered in descending long grades, and gives the results obtained from a series of tests. Twenty-eight wheels of varying weight and design were tested, sixteen of which cracked in the plate. The tests suggest the possibility of improving the design of these wheels.

DONATIONS TO READING ROOM

PUBLICITY METHODS FOR ENGINEERS.

Chic., American Association of Engineers, copyright, 1922. 186 pp., illus., charts, 7½ x 5 in., cloth. $1.50.

The object of this book, as stated in the Preface, is to make plain the principles of presenting to the public, information concerning engineers and to show how this is being accomplished. The subject-matter is based on papers read at the First National Engineering Conference on Public Information held by the American Association of Engineers in Chicago in 1921, at which each paper was presented by a recognized authority on the subject. The Contents are: Some Reasons for Publicity; The Right Conception of Publicity; Ways and Means That Bring Publicity; Getting News in the Newspapers; The Publicity Man and What He Needs to Know; Typical Publicity Problems; Appendix I, Some Approximate Costs for Estimating; Appendix II, A Brief Outline of a Working Plan.

THE YOUNG MAN AND CIVIL ENGINEERING.

By George Fillmore Swain, Past-President, Am. Soc. C. E. N. Y., The Macmillan Company, 1922. 203 pp., 7½ x 5 in., cloth. $2.00.

This volume is one of the Vocational Series designed to offer competent advice to young men on the verge of choosing a profession. Notwithstanding the important issues involved in a man's vocational career, little has been done so far in a practical or systematic way to help college young men to a wise decision in the determination of their life work. The Editor has been able to secure the services of some of the most eminent experts in the country to prepare the respective volumes. This book is a thorough survey of the civil engineering field. It is written in straightforward style and in simple, non-technical language.

RELATIONS OF WISDOM AND PURPOSE.

By Richard Justin McCarty, M. Am. Soc. C. E., The Author, copyright 1922. 190 pp., 9 x 6 in., cloth.

This book, it is stated, is an essay in practical philosophy, the argument discussed being that the nature and practical significance of purposes and the means and methods used in their prosecution and achievement constitute the only available criterion of wisdom. The Contents are: The Purposes of Man; Good and Evil Purposes; Predominance of Good Purposes; Cause, Effect and Principle; Law and Order; Means and Method; Intellectual Efficiency; Forces of Intellectual Efficiency; Free Will and Executive Ability; The Wisdom of Man; Degrees of Human Wisdom; Unlimited Wisdom.

MODERN TUNNELING.

By David W. Brunton and John A. Davis. New Chapters on Railroad Tunneling, by J. Vipond Davies, M. Am. Soc. C. E. Second Edition, Revised and Enlarged. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Limited, 1922. 612 pp., illus., pl., diagrams. 9 x 5½ in., cloth. $6.50. (Donated by Mr. Davies.)

This book is confined chiefly to a discussion of up-to-date methods and equipment for constructing tunnels and adits for mining purposes, such as drainage, transportation, or development, but it also includes those which are used to carry water for power, irrigation, or domestic use, in which the essential features are practically identical with mine tunnels. The authors hope that the suggestions contained therein may result in a saving to the mining industry, of life, energy, and capital that would otherwise be expended for inefficient or useless work.

THE DESIGN OF STEEL MILL BUILDINGS

And the Calculation of Stresses in Framed Structures. By Milo S. Ketchum, M. Am. Soc. C. E. Fourth Edition, Rewritten. N. Y. and Lond., McGraw-Hill Book Company, Inc., 1921. 632 pp., pl., diagrams. 9 x 6 in., cloth. $6.00. (Donated by the Author.)

In this edition, the subject-matter has been rewritten and enlarged, the type has been reset, and the plates have been recast. In his text, the author has covered the calculation of the stresses in framed structures, and also the design of buildings having a self-supporting steel frame with a light covering, usually fireproof. The book is intended to serve as a textbook in structural engineering, and also as a book of reference for engineers.

CONCRETE COMPUTATION CHARTS.

By Richard T. Dana, M. Am. Soc. C. E., and James M. Kingsley. N. Y., Codex Book Company, Inc., 1922. 14 pp., charts, $11\frac{1}{2} \times 8\frac{3}{4}$ in., cloth. $5.00. (Donated by Mr. Dana.)

The purpose of this book of charts, it is stated, is to furnish to the designing engineer, the draftsman, the estimator, and the student a concise and complete apparatus for proportioning the parts and estimating the cost of concrete structures. Careful directions accompany the charts by the aid of which the necessary quantities may be read directly, thus avoiding the necessity of arithmetical or algebraic calculation, minimizing the risks of error always present in such calculations, and greatly expediting the process of design. Their use, it is stated, does not require a knowledge of the rather complex mechanical theory of flexure in reinforced concrete beams.

MEMBERSHIP

(From May 3d to July 20th, 1922)

ADDITIONS

HONORARY MEMBERS

		Date of Membership.
HERSCHEL, CLEMENS. Hydr. Engr., 2 Wall St., New York City	M. Hon. M.	April 21, 1869 June 19, 1922
UNWIN, WILLIAM CATHORNE. Palace Gate Mansions, 29 Palace Gate, Kensington, W. 8, London, England		June 19, 1922

MEMBERS

ADEY, WILLIAM HENRY. Office Engr., Delaware & Hudson Co., Albany (Res., 81 Broadway, Cohoes), N. Y.	Jun. Assoc. M. M.	Feb. 4, 1896 Dec. 3, 1902 May 8, 1922
ANDREWS, GEORGE CROWELL. Water Commr., City of Buffalo, 2 Municipal Bldg., Buffalo, N. Y.	Jun. Assoc. M. M.	Aug. 31, 1909 June 30, 1911 June 20, 1922
BAKER, SYLVESTER CLAY. Engr., M. of W., East St. Louis & Suburban Ry. and Affiliated Companies (Res., 603 North 14th St.), East St. Louis, Ill.	Assoc. M. M.	Sept. 9, 1919 May 8, 1922
BARBER, ALVIN BARTON. Technical Adviser to Govt. of Poland, Care, Col. Logan, 18 rue Tilsitt, Paris, France		May 8, 1922
BARKER, LAWRENCE BYRON. Asst. Engr., San. Dist. of Chicago, 12144 Eggleston Ave., Chicago, Ill		May 8, 1922
BARNES, FRED ASA. Director, School of Civ. Eng., Cornell Univ., Ithaca, N. Y.	Assoc. M. M.	Dec. 7, 1904 June 20, 1922
BEGG, ROBERT BURNS HALDANE. Prof., Civ. Eng., Virginia Polytechnic Inst., Blacksburg, Va.	Assoc. M. M.	Mar. 4, 1913 May 8, 1922
BENNETT, HARRY. Eastern Mgr., Valley Iron Works Co., 350 Madison Ave., New York City	Assoc. M. M.	Nov. 28, 1916 May 8, 1922
BLOSSER, EMMET CHANDLER. State Highway Engr., Columbus, Ohio	Assoc. M. M.	Sept. 11, 1917 May 8, 1922
BOESCH, CLARENCE EDWIN. Cons. Engr. (Gilbert C. White Co.), Box 562, Durham, N. C.	Assoc. M. M.	Nov. 28, 1916 May 8, 1922
BOYD, ROBERT WRIGHT. Engr., Turner Constr. Co., 244 Madison Ave., New York City	Assoc. M. M.	Jan. 8, 1908 June 20, 1922
BRECK, CHARLES RENWICK, JR. Eng. and Reporting Div., J. G. White Eng. Corporation, 43 Exchange Pl., New York City	Assoc. M. M.	Sept. 12, 1916 May 8, 1922
BRENEMAN, PAUL BRUCE. Prof. of Mechanics and Materials of Constr., in Chg. of the Dept. and Laboratory for Testing Materials, The Pennsylvania State Coll., State College, Pa.	Assoc. M. M.	Mar. 2, 1909 June 20, 1922
BROWNE, CHARLES ALLEN. State Highway Engr., 132 East Concord Ave., Orlando, Fla.		June 19, 1922
BUNDY, ORA. Engr. and Contr. (Kroft & Bundy), 417 Kiesel Bldg., Ogden, Utah		April 3, 1922
BURPEE, ROY WILLIAM. 207 West St., Leominster, Mass.		Jan. 16, 1922

MEMBERS—(*Continued*)

		Date of Membership.
BUSHELL, ARTHUR WILLIAM. Div. Engr., State Highway Dept., Thayer Bldg., Norwich, Conn......	Jun. Assoc. M. M.	Oct. 1, 1907 Oct. 7, 1914 June 20, 1922
CHAMBERS, CLOYDE CLEAVER. Div. Engr., The Miami Conservancy Dist., Dayton, Ohio..............	Assoc. M. M.	Mar. 13, 1917 June 20, 1922
CHASE, JOSEPH THEODORE. Mgr. and Engr., Roanoke Rapids Power Co., Roanoke Rapids, N. C................................		June 19, 1922
CLAPP, SIDNEY KINGMAN. Asst. Engr., Board of Water Supply, Grand Gorge, N. Y.............	Assoc. M. M.	April 5, 1905 June 20, 1922
CLOW, GEORGE VALENTINE. Head, Const. Dept., The National Cash Register Co., Dayton, Ohio....	Assoc. M. M.	Mar. 12, 1918 May 8, 1922
CODWISE, HENRY ROGERS. Asst. Prof., Civ. Eng., Polytechnic Inst. of Brooklyn (Res., 25 Garden Pl.), Brooklyn, N. Y..............................	Jun. Affiliate M.	April 2, 1901 April 6, 1909 May 8, 1922
COOLEY, ORRIN FULTON. Asst. Road Commr. of Los Angeles County, 7711 Norton Ave., Hollywood, Calif.	Assoc. M. M.	June 24, 1914 May 8, 1922
COTTON, WILLIAM OWEN. Civ., Municipal, and Irrig. Engr. (Cotton & Wilson), Top Floor, Post Bldg., Idaho Falls, Idaho....................	Jun. Assoc. M. M.	Jan. 17, 1916 April 17, 1917 April 4, 1922
CROCKER, CALVIN IRA. Chf. Engr. of Ferries, Dept. of Plant and Structures, Room 1800, Municipal Bldg., New York City...		June 19, 1922
DE TARNOWSKY, JACQUES. Structural Engr., 403 Vincent Bldg., New Orleans, La..................................		June 19, 1922
DUGAN, CHARLES BEDARD. Mgr., Chicago Office, National Steel Fabric Co., 761 McCormick Bldg., Chicago, Ill.	Assoc. M. M.	Jan. 19, 1920 June 20, 1922
DUNHAM, ROBERT MOORE. Second Vice-Pres. and Gen. Mgr., Texas Willite Road Const. Co., Box 1031, Amarillo, Tex.	Assoc. M. M.	Dec. 3, 1912 May 8, 1922
FARISH, WILLIAM ADAM. Gen. Irrig. Engr., 863 South Berendo St., Los Angeles, Calif.................................		June 19, 1920
FOLWELL, AMORY PRESCOTT. Editor, *Public Works*, 243 West 39th St., New York City (Res., Montclair, N. J.)...............		May 8, 1922
FOWLER, FRANK HOYT. Engr. and Archt. 1319 L. C. Smith Bldg., Seattle, Wash..................	Assoc. M. M.	May 7, 1913 May 8, 1922
FRENCH, ROGER DELAND. Prof., Highway and Municipal Eng., McGill Univ., Montreal, Que., Canada	Jun. Assoc. M. M.	Mar. 6, 1906 Mar. 5, 1912 May 8, 1922
GOODMAN, JOHN SMITH. Div. Engr., Reading Div., P. & R. R. R. (Res., 823 North 5th St.), Reading, Pa..................		Sept. 12, 1921
HALLIDY, ROBERT JAMES. Care, Agent, North Western Ry., Lahore, India		April 3, 1922
HALWAS, GEORGE CARL. Asst. Engr., The Delaware River Bridge Joint Comm., 228 North Delaware Ave., Philadelphia, Pa....		June 19, 1922
HAMMOND, HARRY PARKER. Prof., Hydr. and San. Eng., Polytechnic Inst. of Brooklyn, 99 Livingston St., Brooklyn, N. Y......................	Assoc. M. M.	Jan. 14, 1918 May 8, 1922
HARDING, CARROLL REDE. Asst. Cons. Engr., Southern Pacific Co., 165 Broadway, New York City..............................		June 19, 1922

MEMBERS—(*Continued*)

		Date of Membership.
HASTINGS, EDGAR MORTON. Prin. Asst. Engr., R. F. & P. R. R., Room 207, Broad St. Station, Richmond, Va.	Assoc. M. M.	June 30, 1910 May 8, 1922
HAUN, GEORGE CLEVELAND, With J. E. Hayes Eng. Corporation, Box 243, American Post Office, Shanghai, China	Jun. Assoc. M. M.	Oct. 1, 1912 Jan. 15, 1917 May 8, 1922
HEBARD, ROY WILLIAM. Pres. and Gen. Mgr., R. W. Hebard & Co., Inc., 40 Rector St., New York City	Assoc. M. M.	Feb. 6, 1907 May 8, 1922
HENRY, ORLOFF. Secy-Treas., L. H. Guerin Eng. Corporation, 603 Tulane-Newcomb Bldg., New Orleans, La.		May 8, 1922
HINCKLEY, GEORGE STEVENS. City Engr., Redlands, Calif.	Assoc. M. M.	Oct. 1, 1912 April 4, 1922
HOLLERAN, LESLIE GILBERT. Deputy Chf. Engr., Bronx Parkway Comm., Bronxville (Res., Scarsdale Ave., Tuckahoe), N. Y.		June 19, 1922
HOWARD, JOHN SPENCE. Cons. Engr., 12 East Lexington St., Baltimore, Md.	Assoc. M. M.	Sept. 12, 1916 May 8, 1922
HOWELL, CARL LATHROP. Asst. Engr., City Engr's Office, Room 20, Municipal Bldg. (Res., 192 Wallace Ave.), Buffalo, N. Y.		May 8, 1922
HUNTER, CHARLES MORRIS. Engr. and Gen. Mgr., Pounding Mill Quarry, Pounding Mill, Va.		June 19, 1922
JASPER, THOMAS MCLEAN. Research Asst. Prof. of Eng. Materials, Room 200, Fatigue of Metals Laboratory, Univ. of Illinois, Urbana, Ill.	Assoc. M. M.	Aug. 31, 1915 June 20, 1922
JONES, FONTAINE. Asst. Engr., Wm. M. Piatt, Armington Hotel, Gastonia, N. C.		June 19, 1922
KELLER, TRAUGOTT FRANCIS. Chf. Engr., Dept. of Docks, 1561 East 12th St., Brooklyn, N. Y.		Jan. 16, 1922
KERNS, CHARLES CYRUS. Pilot Engr., Valuation Survey, A. T. & S. F. Ry., 1510 Western Ave., Topeka, Kans.		Jan. 16, 1922
KNIGHT, EARLE KELLY. Contr. and Designing Engr. (The Jobson-Gifford Co.), 30 East 42d St., New York City	Assoc. M. M.	Dec. 4, 1907 May 8, 1922
LITTLE, GEORGE KERR. Supt., National Contract Co. Dam No. 30, Ohio River, Oliver, Ky.	Assoc. M. M.	June 3, 1903 June 20, 1922
LOCHER, CHARLES HUNTER. Constr. Mgr., The Miami Conservancy Dist., Dayton, Ohio		June 19, 1922
LORD, ARTHUR RUSSELL. Cons. Engr. (Tait & Lord, Inc.), 140 South Dearborn St. (Res., 5222 Kenwood Ave.), Chicago, Ill.	Assoc. M. M.	Mar. 13, 1917 June 20, 1922
LOSE, ROBERT GRAHAM. (Spiker & Lose), 519 Forsyth Bldg., Atlanta, Ga.		Jan. 16, 1922
MCFARLAND, HARRY FONTAINE, JR. Chf. Engr., Wichita Falls & Southern R. R.; Asst. Chf. Engr., Wichita County Water Impvt. Dist. No. 1, 1003 Am. National Bank Bldg., Wichita Falls, Tex.	Assoc. M. M.	Aug. 31, 1915 Jan. 16, 1922
MARSHALL, HARRY SCOTT. Chf. Engr. and Field Mgr., The F. K. Vaughn Bldg. Co., 420 Dayton St., Hamilton, Ohio		June 19, 1922
MARTINI, UMBERTO ERNESTO. Via Sardegna 14, Rome, Italy		April 3, 1922

MEMBERS—(*Continued*)		Date of Membership.
MICKEY, CLARK EDWIN. Prof. in Chg., Civ. Eng. Dept., Univ. of Nebraska; Cons. Engr., Nebraska Dept. of Public Works, Univ. of Nebraska, Lincoln, Nebr.	Affiliate Assoc. M. M.	Jan. 6, 1915 Oct. 9, 1917 May 8, 1922
MITCHELL, WILLIAM MONTGOMERY. Asst. Supt., Board of Water Commrs., 176 East Jefferson Ave., Detroit, Mich.	Assoc. M. M.	Jan. 14, 1918 May 8, 1922
PADDOCK, HOWARD CHARLES. Engr., The Turner Constr. Co., 244 Madison Ave., New York City (Res., 11 Park Ave., Caldwell, N. J	Assoc. M. M.	June 1, 1909 May 8, 1922
PEAVY, JOHN ROBERTS. Enfield, N. C		May 8, 1922
PETRY, CHARLES ALOYSIUS. Structural Engr. and Supt. of Constr., Univ. of Illinois, 256 Administration Bldg., Urbana, Ill.	Assoc. M. M.	Nov. 27, 1917 May 8, 1922
PHILLIPS, CALEB NORMAN. Office Engr., The Miami Conservancy Dist., Dayton, Ohio		June 19, 1922
PIRIE, JAMES EDWARD. City Engr., Ballinger, Tex.		April 3, 1922
PROSKAUER, ARTHUR JOSEPH MAYER. Engr., Wiederholdt Constr. Co., 620 Bank of Commerce Bldg., St. Louis, Mo		June 19, 1922
PROVINE, LORING HARVEY. Head, Dept. of Architecture, and Prof., Architectural Eng., Univ. of Illinois, 306 Eng. Hall, Univ. of Illinois, Urbana, Ill.		May 8, 1922
RHODES, WILLIAM HERBERT. Care, Louisiana Highway Comm., Baton Rouge, La		June 19, 1922
RICHEY, JOHN JEFFERSON. Prof., Structural Eng., Agricultural and Mech. Coll. of Texas, College Station, Tex		May 8, 1922
ROBINSON, HERBERT FULWILER. Superv. Engr., U. S. Indian Irrig. Service, 310 Federal Bldg., Albuquerque, N. Mex.	Assoc. M. M.	July 10, 1907 Jan. 20, 1922
ROWE, WALTER ELLSWORTH. Engr. and Mgr., John E. Hand & Sons Co., 17 South Gay St., Baltimore, Md.	Assoc. M. M.	April 16, 1918 April 4, 1922
RUNYON, WILLIAM KERPER. Chf. of Technical Dept., Wessel, Duval & Co., La Merced 624, Lima, Peru	Jun. Assoc. M. M.	April 5, 1898 Oct. 5, 1904 May 8, 1922
SEYBOLT, GEORGE HUDSON. Cons. Engr., 15 Park Row, New York City (Res., 58 Clifton Pl., Jersey City, N. J.)	Assoc. M. M.	Mar. 12, 1918 May 8, 1922
SHAW, BENJAMIN BRUCE. Div. Engr., C. R. I. & P. R. R., Gen. Offices, C. R. I. & P. R. R., Little Rock, Ark.	Assoc. M. M.	Aug. 9, 1920 May 8, 1922
SHAW, GEORGE HERBERT. Chf., Div. of Housing and Sanitation, Dept. of Health, Room 615, City Hall, Philadelphia, Pa	Assoc. M. M.	April 5, 1910 June 20, 1922
SHERTZER, TYRRELL BRADBURY. Constr. Engr., Eastern Bureau, National Lime Assoc., 100 Hamilton Place, New York City	Assoc. M. M.	Oct. 5, 1904 June 20, 1922
SMITH, JAMES ELMO. Mayor of Urbana; Asst. Prof., Civ. Eng., Univ. of Illinois, 801 Indiana Ave., Urbana, Ill.	Assoc. M. M.	Mar. 2, 1915 May 8, 1922

MEMBERS—(*Continued*)

		Date of Membership.
SMITH, WALTER GROVER. Div. Engr., Ohio State Highway Dept., R. F. D. No. 1, Madison Heights, Newark, Ohio	Assoc. M. M.	Sept. 11, 1917 May 8, 1922
SMITH, WALTER LYNES. Bridge Engr., Terminal R. R. Assoc. of St. Louis, St. Louis, Mo.	Assoc. M. M.	Feb. 4, 1914 May 8, 1922
SNELL, ROY MARTIN. Project Mgr., U. S. Reclamation Service, Browning, Mont.	Assoc. M. M.	Sept. 6, 1910 June 20, 1922
STEPHENS, ALLEN WHITMORE. Chf. Engr., Turner Constr. Co., 244 Madison Ave. (Res., 120 East 31st St.), New York City	Assoc. M. M.	June 6, 1911 May 8, 1922
STOCKER, EDWARD CHARLES. Engr., Whangpoo Conservancy Board, Box 651, U. S. Post Office, Shanghai, China	Jun. Assoc. M. M.	April 4, 1911 Nov. 12, 1913 May 8, 1922
TOWLES, THOMAS THOMSON. Chf., Bureau of Design, Dept. of Public Works, Room 301, City Hall, Richmond, Va.		June 19, 1922
VAN NORMAN, HARVEY ARTHUR. Asst. to Chf. Engr., Los Angeles Aqueduct, 207 South Broadway (Res., 1732 North Normandie Ave.), Los Angeles, Calif.		May 8, 1922
VOORHEES, PAUL. Res. Engr., P. & R. R. R.; Supt., The Beaver Creek Water Co., 526 Woodward St., Reading, Pa.	Assoc. M. M.	Feb. 3, 1892 June 20, 1922
WALTON, HARRY. With Public Works Dept., Burma, Care, Thomas Cook & Sons, Rangoon, Burma, India		May 8, 1922
WARDLAW, JAMES THOMPSON. Dist. Engr., Atlanta Office, Lockwood, Greene & Co., 1530 Healey Bldg., Atlanta, Ga.	Assoc. M. M.	June 4, 1913 June 20, 1922
WELD, FRED FALCONER. Associate to the Eng. Faculty, Univ. of Washington; Civ. Engr., 231 Globe Bldg., Seattle, Wash.		June 19, 1922
WELLS, REGINALD WENTWORTH. With Charles W. Leavitt, 18 East 41st St., New York City (Res., 194 Larch Ave., Bogota, N. J.).		May 8, 1922
WERNER, AUGUST JOHN. Chf. Engr., Structural and Plate Depts., Baker Iron Works, 908 West 37th St., Los Angeles, Calif.		April 3, 1922
WILEY, CARROLL CARSON. Asst. Prof., Highway Eng., Univ. of Illinois, 714 South State St., Champaign, Ill.		June 19, 1922
WOODSON, WILLIAM FELIX. With J. Temple Waddill, 208 Real Estate Exchange Bldg. (Res., 2806 Montrose Ave.), Richmond, Va.		June 19, 1922
WOODWARD, EDWIN CARLTON. Engr. and Contr. (Chamberlin-Woodward Co.), Eastland (Res., 1400 Copper St., Fort Worth), Tex.	Assoc. M. M.	Oct. 4, 1905 Nov. 21, 1921

ASSOCIATE MEMBERS

ADAMS, WALTER FRANCIS. 20 Monroe St., San Francisco, Calif.	Jan. 16, 1922
ALEXANDER, EARL CURTIS. Estimating Engr. and Asst. Chf. Engr., Massey Concrete Products Corporation, 6143 Dorchester Ave., Chicago, Ill.	June 19, 1922
ALLEN, JOHN EDWARDS. With Wm. Steele & Sons Co., 1600 Arch St., Philadelphia (Res., 47 Copley Rd., Upper Darby), Pa.	June 19, 1922
BACK, WILLIAM ANTHONY. Estimator and Designer, Raymond Concrete Pile Co., 140 Cedar St., New York City	June 19, 1922

ASSOCIATE MEMBERS—(*Continued*)

		Date of Membership.
BALDWIN, ASA COLUMBUS. 3514 Wallingford Ave., Seattle, Wash..		May 8, 1922
BARTON, WILLIAM HENRY, JR. Instr. in Civ. Eng., Univ. of Pennsylvania, Philadelphia, Pa.		May 8, 1922
BAYER, HARRY LEWIS. Asst. Engr., Dept. of Water Supply, New York City (Res., 528 Thatford Ave., Brooklyn, N. Y.)	Jun. Assoc. M.	June 16, 1919 Nov. 21, 1921
BECK, CARL WILLIAM. Asst. Div. Engr., P. F. W. C. Ry., 629 Park Ave., Avalon, Pittsburgh, Pa.		April 3, 1922
BENHAM, CLAUDE GILBERT. Capt., F. A., U. S. A., 5th Field Artillery, Camp Bragg, N. C.	Jun. Assoc. M.	April 18, 1916 May 8, 1922
BLOCH, MAX. Structural Draftsman, Grade A, U. S. Naval Ordnance Plant, 11 Freeman Court, South Charleston, W. Va..		May 8, 1922
BUCKIUS, CHARLES HENRY. Dist. Engr., Pennsylvania State Highway Dept., New Castle, Pa.		June 19, 1922
BURDEN, HARRY POOLE. Asst. Prof., Civ. Eng., Tufts Coll., Medford (Res., 7 University Ave., Medford Hillside 57), Mass..		June 19, 1922
BURNLEY, SETH. Engr., Bureau of Design, Dept. of Public Works, Charlottesville, Va.		June 19, 1922
BURT, EARLE ANDREWS. Dist. Engr., Los Angeles County Road Dept., 1104 Hall of Records, Los Angeles (Res., Altadena), Calif.	Jun. Assoc. M.	Mar. 12, 1918 May 8, 1922
CAMLIN, WILLIAM JOHN. Designing and Sales Engr., Building Products Co., 67 East Long St., Columbus, Ohio	Jun. Assoc. M.	May 12, 1919 June 19, 1922
CAMP, GEORGE DASHIELL. City Hall, Breckenridge, Tex.	Jun. Assoc. M.	Sept. 12, 1916 April 3, 1922
CAMPBELL, GEORGE LEWIS. Div. Engr., Kansas Highway Comm., 518 South 11th St., Salina, Kans.		May 8, 1922
CHAPIN, DOUGLAS BRYANT. With International Coal Products Corporation (Clinchfield Carbocoal Corporation), South Clinchfield, Va.		June 19, 1922
CHIN, HAM KEE. Asst. Engr. with R. H. Thomson, 508 Seventh Ave., South, Seattle, Wash.	Jun. Assoc. M.	Nov. 28, 1916 May 8, 1922
CHURCH, GAYLORD. Lt.-Commander, C. E. C., U. S. N., U. S. Submarine and Destroyer Base, Astoria, Ore.		May 8, 1922
CHURCH, RAYMOND GILLESPIE. Member, Architectural Faculty, and Bldg. Insp., Montana State Coll., Bozeman, Mont.		May 8, 1922
CORNELIUS, ERNEST HARRY. 411 Central National Bldg., Tulsa, Okla.		July 11, 1921
COSORES, NOAH. Bridge Designer, J. A. L. Waddell, New York City (Res., Palisades Park, N. J.)		June 19, 1922
CRAWFORD, MERLIN CROSS. Constr. Supt., W. E. Callahan Constr. Co., Ennis, Tex.		May 8, 1922
CRITZ, PAUL FRANCIS. Laboratory Chf., Iowa State Highway Comm. (Res., 821 Douglas Ave.), Ames, Iowa	Jun. Assoc. M.	Nov. 9, 1920 April 3, 1922
CROWN, VICTOR MAX. Office Engr., Ulen Contr. Corporation, Casilla 47, Tupiza, Bolivia	Jun. Assoc. M.	Aug. 9, 1920 May 8, 1922
DAVIS, ROY HAROLD. 7043 Merrill Ave., Chicago, Ill.		Jan. 16, 1922

ASSOCIATE MEMBERS—(*Continued*)

Member		Date of Membership.
DAVIS, WILLIAM HAROLD. Res. Engr., West Virginia State Road Comm., 515 West Pike St., Clarksburg, W. Va.		June 19, 1922
DOCKERY, WILLIAM DEE. Bridge Engr., Hunt County, Box 404, Greenville, Tex.		June 19, 1922
DENNIS, LESLIE MORTIMER. Archt. and Engr., 24 South St., Red Bank, N. J.		Jan. 16, 1922
DOWNING, RODERICK LYLE. Chf. of Party, Bureau of Public Roads, U. S. Dept. of Agriculture, 403 Kiesel Bldg., Ogden, Utah.		June 19, 1922
DUFF, CARL MATHIAS. Asst. Prof., Applied Mechanics, Univ. of Nebraska (Res., 326 North 26th St.), Lincoln, Nebr.		May 8, 1922
DUNCAN, CARL RAY. Asst. Div. Engr., Div. 4, West Virginia State Road Comm., 469 High St., Morgantown, W. Va.		May 8, 1922
DUNN, JOSEPH ANDREW. Field Engr., Portland Cement Assoc., 111 West Washington St. (Res., 7209 Harvard Ave.), Chicago, Ill.		June 19, 1922
EHRHART, LEO JOHN. (Chas. Cohen & Leo J. Ehrhart, Inc.), 1932 Arthur Ave., New York City		June 19, 1922
FAIRTRACE, GEORGE DEVORE. City Engr., City Hall, Dallas, Tex.		April 3, 1922
FIRMIN, ALBERT EDWIN. Engr. and Contr. (Burks, Firmin & Hart), Comanche, Tex.		Jan. 16, 1922
FOX, JOHN RUSSELL. Asst. to Contr. Mgr., Bridge and Structural Dept., U. S. Steel Products Co., 609 Rialto Bldg., San Francisco, Calif.		June 19, 1922
FREEMAN, HERMON MARTIN. Civ. and Cons. Engr. (Freeman & Winston), 14 Northfield Ave., West Orange, N. J.		May 8, 1922
GARMEZY, SAMUEL. Chf. Designing Engr., Atlantic Gulf & Pacific Co. Manila, Philippine Islands		May 8, 1922
GENA, JOHN STIRLING. Office Engr., Miami Conservancy Dist., 836 Meredith St., Dayton, Ohio		June 19, 1922
GIBSON, EDMOND HANNON. Asst. Chf., Bureau of Bldg. Inspection, Dept. of Public Safety, Room 303, City Hall, Richmond, Va.		May 8, 1922
GRAHAM, MAT, JR. Engr. and Contr. (Smith-Graham Constr. Co.), Box 456, Augusta, Kans.		June 19, 1922
HALPERN, JOSEPH. Structural Designer, Dept. of Docks, New York City, 778 Trinity Ave., New York City		May 8, 1922
HARRIS, ALEXANDER MASON. Office, Director of Public Works, 301 City Hall, Richmond, Va.		June 19, 1922
HART, RALPH LEMUEL. Chf. Inspection Engr., Distributing House Inspection Dept., Western Elec. Co., Inc., 316 North Lorel Ave., Chicago, Ill.		June 19, 1922
HARTENSTINE, CHARLES JEFFERSON. Chf. Engr., Donnell-Zane Co., Inc., 4002 Woolworth Bldg., New York City		June 19, 1922
HATCH, DONALD MONROE. Supt., Municipal Dept., City of Wyandotte, 205 Van Alstyne Boulevard, Wyandotte, Mich.	Jun. Assoc. M.	Dec. 6, 1920 May 8, 1922
HEALY, CLYDE ELBERT. Prin. Asst. on Eng. Constr., City and County of San Francisco, 357 City Hall, San Francisco, Calif.		April 3, 1922
HERBERT, HARVEY DIXON. Borough Mgr., Carlisle, Pa.		Nov. 21, 1921
HERRMANN, FRANK. Asst. State Engr., Oklahoma State Highway Dept., Oklahoma, Okla.		May 8, 1922

ASSOCIATE MEMBERS—(*Continued*)

		Date of Membership.
HICKOK, CHARLIE WILLIAM. Dist. Engr., Stanton, Grant, and Haskell Counties, Ulysses, Kans...	Jun. Assoc. M.	Mar. 13, 1917 May 8, 1922
HOYT, LAURENCE BRACKETT. Engr. Dept. of Public Works, Div. of Highways, 168 East Emerson St., Melrose, Mass..........		May 8, 1922
HUTCHINSON, GEORGE WILLIS. Asst. Engr., State Highway Comm., Raleigh, N. C..........		June 19, 1922
HYLAND, GEORGE NORMAN. Asst. Engr., Bureau of Highways, City of Philadelphia, 783 City Hall, Philadelphia, Pa..........		June 19, 1922
JACKSON, ROBERT GEORGE. Head of Constr. Dept., Lockwood, Greene & Co., 245 State St., Boston (Res., 8 Clyde Rd., Watertown), Mass..........		Nov. 21, 1921
JONES, KIRBY VIGILINI. Gen. Delivery, Yellow Springs, Ohio.....		May 8, 1922
KEARNEY, JAMES. Cons. Engr., 1270 Broadway, New York City..		Jan. 16, 1922
KEELY, GEORGE VAN SISE. Cons. Engr. (Tidal Eng. Corporation), 18 Henry St., Port of Spain, Trinidad..........		April 3, 1922
KELLER, EUGENE. Res. Engr., Klyce & Kackley, Box 299, Jonesboro, Ark..........		June 19, 1922
KENDALL, CHARLES AINSWORTH. With J. R. Worcester & Co., 79 Milk St., Boston (Res., 68 Winthrop Ave., Wollaston), Mass.		June 19, 1922
KING, THOMAS HENRY. Chf. Engr., Ed Fletcher Co., 924 Eighth St., San Diego, Calif..........		June 19, 1922
KINSEY, FRANK HERBERT. Engr. and Salesman, Edwin Burhorn Co., 25 West Broadway, New York City (Res., 122 Bigelow St., Newark, N. J.)..........		June 19, 1922
KRAKAUER, JAY FRANK. Chf., Survey Bureau, The New York Edison Co., 92 Vandam St. (Res., 1015 Longwood Ave.), New York City..........		June 19, 1922
LANGENHEIM, RALPH LOUIS. Asst. Prof., Dept. of Civ. Eng., Univ. of Cincinnati, 1627 Grantwood Ave., Cincinnati, Ohio......		June 19, 1922
LUKENS, HARRY MAXWELL. Office and Designing Engr., Wurster Constr. Co., 583 North New Hampshire St., Los Angeles, Calif..........		Nov. 21, 1921
MACCARTHY, THOMAS GEORGE. 109 North Ninth St., Manhattan, Kans..........		June 19, 1922
MCCAULLY, WILLIAM HENRY. Engr. of Constr., Montgomery, Ward & Co., 439 Maple Ave., Winnetka, Ill..........		May 8, 1922
MCFADDEN, GAYLE. (Carr & McFadden), Box 220, West Palm Beach, Fla..........		May 8, 1922
MCILYAR, WILLIAM KENT. Engr., W. E. Callahan Constr. Co., 718 City National Bank Bldg., Wichita Falls, Tex..........		June 19, 1922
MCKEAN, ALEXANDER MATTHEWS, JR. Asst. to Engr., Mexican Petroleum Corporation, 120 Broadway, New York City (Res., 142 St. Pauls Pl., Brooklyn, N. Y.)..........	Jun. Assoc. M.	April 18, 1916 May 8, 1922
MCMASTER, ALLEN SHELLY. Box 130, Forest Park Station, Fort Worth, Tex..........		May 8, 1922
MCSWEENEY, THOMAS FRANCIS. Constr. Engr., Eng. Service & Constr. Co., Boston (Res., 1 Salem End. Rd., Framingham), Mass..........	Jun. Assoc. M.	May 12, 1919 May 8, 1922

ASSOCIATE MEMBERS—(*Continued*)

	Date of Membership.
MADDOX, WALTER GARNETT. Asst. Chf. Engr., Unit Constr. Co., 1225 Title Guaranty Bldg., St. Louis, Mo	June 19, 1922
MAHER, JOHN LAWRENCE. Div. Engr., B. & O. R. R., 5374 Chew St., Germantown, Philadelphia, Pa	June 19, 1922
MARCK, JOSEPH ALBERT. (Marck Eng. & Contr. Co.), 373 Fulton St., Brooklyn, N. Y	May 8, 1922
MARTEL, ROMEO RAOUL. Associate Prof., California Inst. of Technology, Pasadena, Calif	June 19, 1922
MATTHEWS, HOMER MITCHELL. Office Engr., Tepexic Constr., Mexican Light & Power Co., Necaxa, Pueblo, Mexico	June 19, 1922
MAURER, HENRY LOUIS. Engr., Omaha Steel Works, 2541 North 49th St., Omaha, Nebr	April 3, 1922
MELENDY, RALPH PETER. State Contr. Mgr., Lehigh Portland Cement Co., Box 573, Wichita, Kans	April 3, 1922
MILBURN, THOMAS YANCEY. Vice-Pres., Milburn, Heister Co., Box 522, Durham, N. C	May 8, 1922
MILLER, HARRY EDGAR. Director and Chf. Engr., State Board of Health, Raleigh, N. C	June 19, 1922
MILLS, FREDERICK WILLIAM. Senior Highway Engr., Bureau of Public Roads, U. S. Dept. of Agriculture, 515 Fourteenth St., Room 604, Washington, D. C	May 8, 1922
MORTON, GEORGE WILLIAM. Cadastral Engr., Gen. Land Office, Div. E (Res., 1830 California St., N. W., Apartment 2), Washington, D. C	June 19, 1922
MOSS, EARLE BRISTOL. Appraiser, Bureau of Assessment and Taxation, Office, City Assessor, Niagara Falls, N. Y	Nov. 21, 1921
MURCHISON, EDWARD TOWLER. Asst. Engr., San. Dist. of Chicago (Res., 7142 Evans Ave.), Chicago, Ill	April 3, 1922
NASH, PHILIP CURTIS. Dean and Prof., Civ. Eng., Antioch Coll., Yellow Springs, Ohio	June 19, 1922
NEFF, STEWART SMITH. Hotel Judson, 53 Washington Sq., New York City	April 3, 1922
NEWELL, WILLIAM CLAYTON. Engr. in Chg. for Wheeler & Worthington, 340 West 12th St., Casper, Wyo	Nov. 21, 1921
NICOL, HERBERT ERSKINE. With Sewerage Comm., City of Milwaukee, 505 Newton Ave., Milwaukee, Wis	May 8, 1922
NORCROSS, ARCHER RICE. 105 Madrona, Mill Valley, Calif	June 19, 1922
OGLE, ALFRED LOUIS. Project Engr., State Highway Dept., West Point, Nebr	June 19, 1922
ORTMAN, FRANK ANDREW. 1502 Seventeenth St., Detroit, Mich	June 19, 1922
PETTIGREW, ROBERT LESLIE. Lieut., C. E. C., U. S. N.; Senior Asst. to Public Works Officer, Navy Yard, Norfolk, Va	June 19, 1922
PFAU, ALBERT LINCOLN, JR. Gen. Contr., Box 1852, St. Petersburg, Fla	May 8, 1922
PHELAN, VINCENT BALDWIN. Accountant, U. S. Railroad Administration, 466 Lexington Ave., Room 723, New York City	June 19, 1922
PHIPPS, FRANCIS HARLOE. Asst. Engr., Board of Estimate and Apportionment, Tunnel Div., Municipal Bldg. (Res., 257 West 112th St.), New York City	Jun. Mar. 9, 1920 Assoc. M. May 8, 1922

ASSOCIATE MEMBERS—(*Continued*)

		Date of Membership.
PINCUS, SOL. Associate San. Engr., San. Dist. No. 1, U. S. Public Health Service, 116 Custom House (Res., 255 West 108th St.), New York City		May 8, 1922
PRITCHETT, JOHN WALLER. Engr., State Board of Water Engrs., Austin, Tex.		May 8, 1922
PROKES, CHARLES ALBERT. 14 Cedar Terrace, Hot Springs, Ark.		June 19, 1922
PUNG, WILLIAM SING-CHONG. With Truscon Steel Co., Am. Trading Co., Agt., 3 Canton Rd., Shanghai, China	Jun. Assoc. M.	May 31, 1916 April 3, 1922
RAWN, A. M. Irrig. Mgr., King Hill Project, U. S. Reclamation Service, Box 101, King Hill, Idaho		June 19, 1922
REESE, RAYMOND CASTLE. Care, Building Products Co., Box 416, Toledo, Ohio	Jun. Assoc. M.	Nov. 27, 1917 June 19, 1922
RICE, ERNEST GRAHAM. Prin. Engr., Continental Pipe Mfg. Co., 211 Lewis Bldg., Portland, Ore.		June 19, 1922
ROBINSON, JOSEPH FLADING. Vice-Pres., Maloney Paving Co., Inc., 222 C St., N. W., Washington, D. C.		May 8, 1922
SAUNDERSON, FRANKLIN WILLIAM. Care, Slater House, Woodridge, N. Y.		May 8, 1922
SCHWORM, FRED GAST. Asst. Engr., Bridge Div., Bureau of Highways, City of Philadelphia, 2646 South Dewey St., Philadelphia, Pa.		June 19, 1922
SEILER, JAMES FERRIS. Bridge Engr., Wyoming State Highway Dept., 219 West 34th St., Cheyenne, Wyo.		May 8, 1922
SHEPPARD, NORMAN KIRKWOOD. Structural Designer, Dept. of Street Railways, City of Detroit, 6417 Vinewood Ave., Detroit, Mich.	Jun. Assoc. M.	Dec. 3, 1913 May 8, 1922
SHUMAKER, JOHN PERRY. Chf. Engr. of Constr., State Dept. of Highways and Public Works, Columbus, Ohio		Jan. 16, 1922
SIELKE, ALBERT VICTOR. Cons. Engr., 1466 Rosedale Ave., New York City	Jun. Assoc. M.	Oct. 11, 1920 May 8, 1922
SIMPSON, GUSTAVUS SAILER. 325 Guarantee Trust Bldg., Atlantic City, N. J.		May 8, 1922
SMITH, SYDNEY HUGH. (Smith & Reeves), Box 122, Mitchell, S. Dak.		June 19, 1922
SMITH, WILLIAM ANDREW. City Engr., Rifle, Colo.	Jun. Assoc. M.	Oct. 1, 1913 May 8, 1922
SORONDO, RAPHAEL VALENTIN. Chf. Engr., Ferro Carril del Norveste, 65 Cardenas St., Havana, Cuba		April 25, 1921
SPANN, WILLIAM MIMS. Dist. Engr., State Highway Comm., Helena, Mont.		June 19, 1922
SPEIR, OSWALD, JR. Res. Engr., Lindsay Strathmore Irrig. Dist., Lindsay, Calif.	Jun. Assoc. M.	Oct. 14, 1919 April 3, 1922
STEVENSON, EBERLE UPSHAW. U. S. Highway Engr., Bureau of Public Roads, 1912 F. & M. Bank Bldg., Fort Worth, Tex.	Jun. Assoc. M.	Jan. 19, 1920 June 19, 1922
SWIFT, ANGUS VAN AUSDOL. Structural Engr., Decatur Cornice & Roofing Co., Inc., Box 502, Albany, Ala.		June 19, 1922
TEETER, THOMAS ANDERSON HENDRICKS. Civ. and Hydraulic Engr., Wheeldon Annex, Portland, Ore.		June 19, 1922

REINSTATEMENTS

ASSOCIATE MEMBERS	Date of Reinstatement.
WILSON, HARRY PERCIVAL	June 19, 1922

AFFILIATES	
BRITTON, JOHN ALEXANDER	June 19, 1922

RESIGNATIONS

ASSOCIATE MEMBERS	Date of Resignation.
FAIDLEY, LLOYD HARRISON	Dec. 31, 1921

DEATHS

ALLEN, RALPH BENJAMIN. Elected Associate Member, March 13th, 1917; died June 17th, 1922.

BALDWIN, ARCHIBALD STUART. Elected Member, December 6th, 1905; died June 26th, 1922.

BENSEL, JOHN ANDERSON. (*Past-President.*) Elected Junior, September 2d, 1885; Member, March 4th, 1891; died June 19th, 1922.

DE VARONA, IGNACIO MAREA. Elected Member April 7th, 1886; died May 12th, 1922.

EDES, WILLIAM CUSHING. Elected Junior, September 1st, 1886; Member, November 4th, 1896; died May 25th, 1922.

FIELD, GEORGE RUSSELL. Elected Member, November 6th, 1907; died May 1st, 1922.

FLAGLER, CLEMENT ALEXANDER FINLEY. Elected Member, March 13th, 1917; died May 7th, 1922.

FROST, HARRY HENRY. Elected Associate Member, June 4th, 1913; died January 26th, 1922.

GANSER, SYLVAN EARLE. Elected Associate Member, January 2d, 1912; Member, January 18th, 1921; died April 14th, 1922.

HAINES, HENRY STEVENS. Elected Member, November 2d, 1887; died June 25th, 1922.

HULL, WALTER LAWRENCE. Elected Associate Member, January 19th, 1920; died June 20th, 1922.

KNEEDLER, DAVID HENRY LANE. Elected Member, March 9th, 1920; died February 20th, 1922.

KRIGBAUM, LOWELL GAYNOR. Elected Junior, November 4th, 1914; Associate Member, August 9th, 1920; died May, 1921.

POWERS, CORNELIUS VAN VORST. Elected Member, March 1st, 1905; died June 18th, 1922.

SHOEMAKER, JOHN EARL. Elected Associate Member, June 6th, 1911; died June 22d, 1922.

WAGONER, LUTHER. Elected Member, May 2d, 1906; died July 1st, 1922.

Total Membership of the Society, July 20th, 1922, 10 487.

CURRENT CIVIL ENGINEERING LITERATURE

KEY TO ABBREVIATED REFERENCES TO PUBLICATIONS INDEXED*

Abbreviated References.	Publication.	Place.
Am. C. Inst	*American Concrete Institute, Proceedings* (Y.)	Detroit
A. I. E. E.	*American Institute of Electrical Engineers, Journal* (M.)	New York
A. R. E. A.	*American Railway Engineering Association, Proceedings* (Y.)	Chicago
A. S. T. M.	*American Society for Testing Materials, Proceedings* (Y.)	Philadelphia
Am. Soc. C. E.	*American Society of Civil Engineers, Proceedings* (M.)	New York
Am. Soc. Mun. Impvts.	*American Society for Municipal Improvements, Proceedings* (Y.)	New York
Am. W. W. Assoc.	*American Waterworks Association, Journal* (Bi-M.)	Baltimore
Am. Wood Prs. Assoc.	*American Wood Preservers Association, Proceedings* (Y.)	Baltimore
Ann. P. et C.	*Annales des Ponts et Chaussées* (Bi-M.)	Paris
Ann. T. P. Belg.	*Annales des Travaux Publics de Belgique* (Bi-M.)	Brussels
Assoc. Ing. Gand	*Annales de l'Association des Ingénieurs sortis des Ecoles Spéciales de Gand* (Q.)	Ghent
Bost. Soc. C. E.	*Boston Society of Civil Engineers, Journal* (M.)	Boston
Can. Engr	*Canadian Engineer* (W.)	Toronto
Cem. Eng.	*Cement and Engineering News* (M.)	Chicago
Cornell C. E.	*Cornell Civil Engineer* (M.)	Ithaca
Dock & Harbour	*Dock and Harbour Authority* (M.)	London
Eisenbau	*Der Eisenbau* (M.)	Leipsig
Eng.	*Engineering* (W.)	London
Eng. Club, St. L.	*Engineers Club, St. Louis, Journal* (Bi-M.)	St. Louis
Eng. & Contr.	*Engineering and Contracting* (W.)	Chicago
Eng. Inst. Can.	*Engineering Institute of Canada, Journal* (M.)	Montreal
Eng. N. R.	*Engineering News-Record* (W.)	New York
Engrs. Soc. Pa.	*Engineers' Society of Pennsylvania, Journal* (M.)	Harrisburg
Engrs. Soc. W. Pa.	*Engineers' Society of Western Pennsylvania, Journal* (M.)	Pittsburgh
Engr.	*Engineer* (W.)	London
Engrs. & Eng.	*Engineers and Engineering, Engineers' Club of Philadelphia* (M.)	Philadelphia
Gen. Civ.	*Le Génie Civil* (W.)	Paris
Gesund. Ing.	*Gesundheits Ingenieur* (W.)	Munich
Inst. C. E.	*Institution of Civil Engineers Minutes of Proceedings* (Q.)	London
Inst. Mun. & Co. Engrs.	*Institution of Municipal and County Engineers, Journal* (W.)	London
Int. Ry. Assoc	*International Railway Association, Bulletin* (M.)	Brussels
Land. Arch	*Landscape Architecture* (M.)	Harrisburg
Mech. Eng	*Mechanical Engineering* (M.) *Journal of the American Society of Mechanical Engineers*	New York
[illegible]	*Comptes Rendus* (Q.)	Paris
Ver. deu. Ing.	*Verein deutscher Ingenieure, Zeitschrift* (W.)	Berlin
West. Ry. Club	*Western Railway Club, Proceedings* (M.)	Chicago
West. Soc. Engrs.	*Western Society of Engineers, Journal* (M.)	Chicago
Zeit. Bau	*Zeitschrift fur Bauwesen* (Q.)	Berlin
Z. d. Bauver	*Zentralblatt der Bauverwaltung* (Semi-Weekly)	Berlin

* Y = Yearly; Q = Quarterly; M = Monthly; F = Fortnightly; W = Weekly.

REINSTATEMENTS

ASSOCIATE MEMBERS	Date of Reinstatement.
WILSON, HARRY PERCIVAL	June 19, 1922

AFFILIATES	
BRITTON, JOHN ALEXANDER	June 19, 1922

RESIGNATIONS

ASSOCIATE MEMBERS	Date of Resignation.
FAIDLEY, LLOYD HARRISON	Dec. 31, 1921

DEATHS

ALLEN, RALPH BENJAMIN. Elected Associate Member, March 13th, 1917; died June 17th, 1922.

BALDWIN, ARCHIBALD STUART. Elected Member, December 6th, 1905; died June 26th, 1922.

BENSEL, JOHN ANDERSON. (*Past-President.*) Elected Junior, September 2d, 1885; Member, March 4th, 1891; died June 19th, 1922.

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FROST, HARRY HENRY. Elected Associate Member, June 4th, 1913; died January 26th, 1922.

GANSER, SYLVAN EARLE. Elected Associate Member, January 2d, 1912; Member, January 18th, 1921; died April 14th, 1922.

HAINES, HENRY STEVENS. Elected Member, November 2d, 1887; died June 25th, 1922.

ERRATUM

Proceedings, VOL. XLVIII, PAGE 538 (AUGUST, 1922).

For HAINES, HENRY STEVENS, read HAINES, HENRY SNOWDEN.

WAGONER, LUTHER. Elected Member, May 2d, 1906; died July 1st, 1922.

Total Membership of the Society, July 20th, 1922, 10 487.

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A. I. E. E.	*American Institute of Electrical Engineers, Journal* (M.)	New York
A. R. E. A.	*American Railway Engineering Association, Proceedings* (Y.)	Chicago
A. S. T. M.	*American Society for Testing Materials, Proceedings* (Y.)	Philadelphia
Am. Soc. C. E.	*American Society of Civil Engineers, Proceedings* (M.)	New York
Am. Soc. Mun. Impvts.	*American Society for Municipal Improvements, Proceedings* (Y.)	New York
Am. W. W. Assoc.	*American Waterworks Association, Journal* (Bi-M.)	Baltimore
Am. Wood Prs. Assoc.	*American Wood Preservers Association. Proceedings* (Y.)	Baltimore
Ann. P. et C.	*Annales des Ponts et Chaussées* (Bi-M.)	Paris
Ann. T. P. Belg.	*Annales des Travaux Publics de Belgique* (Bi-M.)	Brussels
Assoc. Ing. Gand.	*Annales de l'Association des Ingénieurs sortis des Ecoles Spéciales de Gand* (Q.)	Ghent
Bost. Soc. C. E.	*Boston Society of Civil Engineers, Journal* (M.)	Boston
Can. Engr.	*Canadian Engineer* (W.)	Toronto
Cem. Eng.	*Cement and Engineering News* (M.)	Chicago
Cornell C. E.	*Cornell Civil Engineer* (M.)	Ithaca
Dock & Harbour	*Dock and Harbour Authority* (M.)	London
Eisenbau	*Der Eisenbau* (M.)	Leipsig
Eng.	*Engineering* (W.)	London
Eng. Club, St. L.	*Engineers Club, St. Louis, Journal* (Bi-M.)	St. Louis
Eng. & Contr.	*Engineering and Contracting* (W.)	Chicago
Eng. Inst. Can.	*Engineering Institute of Canada, Journal* (M.)	Montreal
Eng. N. R.	*Engineering News-Record* (W.)	New York
Engrs. Soc. Pa.	*Engineers' Society of Pennsylvania, Journal* (M.)	Harrisburg
Engrs. Soc. W. Pa.	*Engineers' Society of Western Pennsylvania, Journal* (M.)	Pittsburgh
Engr.	*Engineer* (W.)	London
Engrs. & Eng.	*Engineers and Engineering, Engineers' Club of Philadelphia* (M.)	Philadelphia
Gen. Civ.	*Le Génie Civil* (W.)	Paris
Gesund. Ing.	*Gesundheits Ingenieur* (W.)	Munich
Inst. C. E.	*Institution of Civil Engineers Minutes of Proceedings* (Q.)	London
Inst. Mun. & Co. Engrs.	*Institution of Municipal and County Engineers, Journal* (W.)	London
Int. Ry. Assoc.	*International Railway Association, Bulletin* (M.)	Brussels
Land. Arch.	*Landscape Architecture* (M.)	Harrisburg
Mech. Eng.	*Mechanical Engineering* (M.) *Journal of the American Society of Mechanical Engineers*	New York
Mil. Engr.	*Military Engineer* (M.)	Washington
Min. & Metal.	*Mining and Metallurgy* (M.) *American Institute of Mining Engineers*	New York
Mun. & Co. Eng.	*Municipal and County Engineering* (M.)	Indianapolis
N. E. W. W. Assoc.	*New England Water Works Association, Journal* (M.)	Boston
N. Y. R. R. Club	*New York Railroad Club, Proceedings* (M.)	Brooklyn
Oest. Ing. Arch. Ver.	*Oesterreichischer Ingenieur und Architekten Verein, Zeitschrift* (W.)	Vienna
Power	*Power* (W.)	New York
Rev. Gen.	*Revue Générale des Chemins de Fer* (M.)	Paris
Ry. Age	*Railway Age* (W.)	New York
Ry. Main. Engr.	*Railway Maintenance Engineer* (M.)	Chicago
Ry. Rev.	*Railway Review* (W.)	Chicago
Schw. Bauz.	*Schweizerische Bauzeitung* (W.)	Zurich
Sci. Am.	*Scientific American* (M.)	New York
Soc. Ing. Civ. Fr.	*Société des Ingénieurs Civils de France, Mémoires et Comptes Rendus* (Q.)	Paris
Ver. deu. Ing.	*Verein deutscher Ingenieure, Zeitschrift* (W.)	Berlin
West. Ry. Club	*Western Railway Club, Proceedings* (M.)	Chicago
West. Soc. Engrs.	*Western Society of Engineers, Journal* (M.)	Chicago
Zeit. Bau.	*Zeitschrift fur Bauwesen* (Q.)	Berlin
Z. d. Bauver.	*Zentralblatt der Bauverwaltung* (Semi-Weekly)	Berlin

* Y = Yearly; Q = Quarterly; M = Monthly; F = Fortnightly; W = Weekly.

A. Applied Sciences

a. Processes of Calculation

2. Graphical and Nomographical Processes

Graphics Applied to Economic Location of Buildings.* Charles P. Dunn. Eng. N. R. Apr. 27, '22.

Sur l'Utilité des Formes Projectives en Géométrie Descriptive. (On the Use of Projective Forms in Descriptive Geometry.) A. Claeys. Assoc. Ing. Gand. Pt. 1, '22.

Abaque pour le Calcul des Poutres en T Soumises à Flexion Simple.* (Table for the Calculation of T-Beams Under Simple Flexure.) R. Coppée. Assoc. Ing. Gand. Pt. 1, '22.

B. Applied Mechanics

a. Mechanics of Solids (Strength of Materials)

1. Processes of Measurement and Methods of Testing

Notes on the Single Blow Impact Test on Notched Bars.* Richard Henry Greaves and Harold Moore. Inst. C. E. 1920–21, Pt. 1.

On the Characteristics of Notched-Bar Impact Tests.* Thomas Ernest Stanton and Reginald George Cyril Batson. Inst. C. E. 1920–21, Pt. 1.

Shock Tests and Their Standardization: Including the Effect of High Velocities on Impact Up to 2 870 Feet per Second.* Robert Abbott Hadfield and Sidney Arthur Main. Inst. C. E. 1920–21, Pt. 1.

Stresses in Concrete Drain Tile.* J. A. Wise. Eng. & Contr. May 10, '22.

2. Elastic Solids

The Effect of Overstrain on the Impact Figures of Steel.* Richard Morgan Jones and Richard Henry Greaves. Inst. C. E. 1920–21, Pt. 1.

Mechanical Stresses in Transmission Lines.* E. Maerker. Can. Engr. Apr. 25, '22.

Tests of Twelve Large Columns. F. Voss. (From *Der Bauingenieur.*) Eng. N. R. May 25, '22.

Zulässige Inanspruchnahme der Brückenbaustoffe.* (Permissible Loads for Bridge Building Materials.) Wilhelm Hauser. Oest. Ing. Arch. Ver. Mar. 31, '22.

Neuere Fortschritte der technischen Elastizitätstheorie auf dem Gebiete der Platten und Schalen. (Recent Advances in the Technical Elasticity Theory as Regards Plates and Slabs.) Ver. deu. Ing. Apr. 15, '22.

Graphikon für die Berechnung von Plattenbalken und deren wirtschaftliche Bemessung bei reiner Biegung.* (Graphics for the Calculation of Plate Girders and Their Economic Proportioning Under Pure Flexure.) W. Kindler. Schw. Bauz. Apr. 29, '22.

6. Heterogeneous Solids (Reinforced Materials)

Calcul Général des Pièces à Deux Appuis à Encastrement Partiel.* (General Calculation of Members with two Supports Partially Imbedded.) Louis Gellusseau. Gen. Civ. Serial beginning Apr. 8, '22.

7. Pulverulent Masses (Earth Pressure)

Transmission of Pressure Through Solids and Soils and the Related Engineering Phenomena.* George Paaswell. Am. Soc. C. E. May, '22.

b. Hydraulics

2. Physical Hydraulics (Orifices, Pipes, Channels, Waves)

Making 30-Inch Flexible Joint Cast-Iron Pipe.* William G. Hammerstrom. Eng. N. R. May 11, '22.

Anomalous Results in Venturi Flume and Meter Tests.* William J. Walker. Eng. N. R. May 11, '22.

On the Proper Value of Kutter's *n* for Sewer Computations.* Charles W. Sherman. Eng. N. R. June 8, '22.

3. Industrial Hydraulics

Developments in High-Speed Runners for Hydraulic Turbines.* Frank H. Rogers. Power Apr. 25, '22.

Power Development in the Southeast.* Chas. G. Adsit. Mech. Eng. May, '22.

Progress in Water-Wheel Design.* (From Report of National Elec. Light Assoc.) Eng. N. R. June 1, '22.

Three 70 000 Hp. Hydraulic Turbines to be Installed at Niagara Falls.* Power June 6, '22.

c. Pneumatics

3. Industrial Pneumatics

Kraft-Speicherungs-Anlagen mittels komprimierter Luft.* (Plants for Storing Up Power by Means of Compressed Air.) W. E. Trümpler. Schw. Bauz. Apr. 29, '22.

C. Materials of Construction and General Processes

a. Lime, Cement, Mortar, Concrete, Brick, Bitumen, Timber, Gravel, etc.

The Electrical Operation of the River Rock Gravel Company.* A. V. Thompson. Cem. Eng. May, '22.

Alumina Cement; Its Development, Use and Manufacture. Henry S. Spackman. Eng. N. R. May 18, '22.

Le Durcissement des Liants Hydrauliques. Qualités et Réception des Chaux. (The Setting of Hydraulic Binders. Quality and Acceptance Tests of Limes.) E. Camerman. Assoc. Ing. Gand Pt. 1, '22.

Deutscher Marmor. (German Marble.) Otto Burre. Z. d. Bauver. Apr. 15, '22.

b. Metals

Association Belge de Standardisation. Rapport No. 9. Standardisation (Provisoire) des Cornières Egales.* (Belgian Standardization Association. Report No. 9. Standardization (Provisional) of Equal Angle Irons.) Assoc. Ing. Gand Pt. 1, '22.

c. Preservation and Use of Materials. Painting, Waterproofing

Tests on Sea-Water Corrosion of Structural Materials. (From *London Times Engineering Supplement.*) Eng. & Contr. May 21, '22.

f. Rock Excavation. Mining. Rock Removal

Abstracts of Institute Papers.* Min. & Metal. May, '22.
Possibilities in Liquid Air Explosives.* Eugene Roy. (From *Compressed Air Magazine.*) Eng. & Contr. May 17, '22
Abstracts of Institute Papers. Min. & Metal. June. '22.
Druckluftwirtschaft auf Kohlengruben. (Economy of Compressed Air in Coal Mines.) Nover. Ver. Deu. Ing. Apr. 8, '22.

g. Execution of Works. Specifications

1. Of Masonry
Estimating Brickwork-Labor Cost. Chas. F. Dingman. Eng. N. R. June 8, '22.
3. Of Wood
Stanford Stadium Built of Timber on Earth Fill.* E. E. Carpenter. Eng. N. R. May 4, '22.
Home Treatment of Lumber for Mill Roof with Creosote.* William E. Rudolph. Eng. N. R. May 25, '22.
4. Of Metal
Erection of Steel Structures by Arc Welding.* H. L. Unland. Engrs. Soc. W. Pa. Dec., '21.
5. Of Reinforced Concrete
Reinforced Concrete for Ship-Construction.* Thomas Bertrand Abell. Inst. C. E. 1920–21, Pt. 1.
Reinforced Concrete.* W. W. Grierson. Int. Ry. Assoc. Apr., '22.

x. Miscellaneous

Design and Construction of Light-Weight Floor Systems.* Jacob Fruchtbaum. Eng. N. R. May 4, '22.

h. Foundations

Load Tests of Piers for Chicago New Union Station.* Eng. N. R. May 18, '22.
Shifting of Bridge Pier Stopped After 35 Years.* M. F. Clements. Ry. Age June 10, '22.
Caissons en Béton Armé, pour Fondations à l'Air Comprimé.* (Reinforced Concrete Caissons for Foundation Work with Compressed Air.) J. Eugenio Ribera. Gen. Civ. Apr. 8, '22.

i. Coffer-dams

Caisson Cofferdam Foundation with Special Bracing.* T. Kennard Thomson. Eng. N. R. June 1, '22.

k. Tunnels and Tunneling-Shields

Driving a 32-Ft. Hydraulic Pressure Tunnel Around the American Niagara.* Eng. N. R. Apr. 27, '22.
Rochester Begins Work of Making Subway Out of Erie Canal.* Edwin A. Fisher. Eng. N. R. May 4, '22.
Research Reveals How to Ventilate the Hudson River Vehicular Tunnel. Robert G. Skerrett. (From *Compressed Air Magazine.*) Eng. & Contr. May 17, '22.
Converting a Tunnel Into an Open Cut on a Busy Line.* W. S. McFetridge. Ry. Age June 3, '22.

D. Highways

a. Location

Should Highway Curves Contain Transition Spirals? Ernest L. Culbreth. Eng. N. R. May 11, '22.
Safety and Beauty in the Layout and Design of Highways. A. R. Hirst. (Paper read before Am. Assoc. of State Highway Officials.) Can. Engr. June 6, '22.
Method of Figuring Street Intersection Grades.* A. B. Cutter. (From *Concrete Highway Magazine.*) Eng. & Contr. June 7, '22.

b. Load Resistance

Developments in the Scientific Testing of Road Surfaces, Subgrades and Materials.* Eng. Contr. June 7, '22.

c. Construction

Development in Pavement Construction. Charles M. Upham. (Paper read before Am. Assoc. of State Highway Officials.) Can. Engr. Apr. 25, '22.
Concrete Road Specifications. H. K. Bishop. Cem. Eng. May, '22.
Local Mineral Aggregate in Bituminous Macadam Roads. W. A. Welch. (Paper read before Am. Road Builders' Assoc.) Can. Engr. May 2, '22.
Selection of Mineral Aggregates for Concrete Roads. Duff A. Abrams. (Paper read before Am. Road Builders' Assoc.) Eng. & Contr. May 3, '22.
Getting Ready for the Pavement. R. A. Macgregor. (Paper read before City Paving Conference.) Eng. & Contr. May 3, '22.

What is a Day's Work Laying Concrete Pavement.* H. K. Davis. Eng. N. R. May 4, '22.
Importance of Surface Finish on Roads. H. Eltinge Breed. (Paper read before Am. Road Builders' Convention.) Can. Engr. May 9, '22.
Standardized Specifications for Mineral Aggregates for Asphalt Pavements. Roy M. Green. (Paper read before Am. Road Builders' Assoc.) Can. Engr. May 16, '22.
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d. Maintenance

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h. Vehicles. Automobiles=Traffic

The Pittsburgh Traffic Count.* Winters Haydock. Engrs. Soc. W. Pa. Jan., '22.
Ohio Boulevard Extension at Terre Haute, Indiana. George J. Stoner. Mun. & Co. Eng. May, '22.
Motor Truck Transportation. J. F. Winchester. (Paper read before New Jersey Highway Assoc.) Eng. & Contr. May 3, '22.
Adequate Ranking and Parking Facilities for Vehicles.* W. P. Eno. (Abstract of paper read before National Highway Traffic Assoc.) Eng. & Contr. May 3, '22.
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Notes on the Arrangement and Working of a Highways Department Central Depot.* B. C. Hammond. Inst. Mun. & Co. Engrs. May 20, '22.

E. Bridges, Viaducts, and Arches

a. Timber Bridges and Viaducts

Two-Hinged Timber Arch Used As Temporary Railroad Bridge.* W. J. H. Fogelstrom. Eng. N. R. May 4, '22.

b. Iron or Steel Bridges and Viaducts

Cannon Street Bridge Strengthening.* George Ellson. Inst. C. E. 1920–21, Pt. 1.
The Continuous Truss Bridge Over the Ohio River at Sciotoville, Ohio, of the Chesapeake and Ohio Northern Railway.* Discussion, C. A. P. Turner, T. Kennard Thomson, and Charles Evan Fowler. Am. Soc. C. E. May, '22.
Erection of Hurricane Gulch Arch Bridge on Alaska Government Railway.* Ry. Rev. May 6, '22.
Castleton Bridge and Freight Cut-Off Started.* Ry. Age May 27, '22.
Large Steel Arch Bridge Ribs Encased in Gunite.* C. B. McCullough. Eng. N. R. June 8, '22.
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Sparsamkeit im Eisenbrückenbau.* (Economy in Iron Bridge Construction.) Friedrich Hartmann. Oest. Ing. Arch. Ver. Serial beginning Mar. 31, '22.
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d. Concrete and Reinforced Concrete Bridges and Viaducts

Reconstruction of a Viaduct.* Frederick William Adolph Handman. Inst. C. E. 1920–21, Pt. 1.
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Expansion and Overturning Causes Damage to Concrete Bridge.* Harlan H. Edwards. Eng. N. R. Apr. 27, '22.

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Hillhurst Bridge, Calgary.* John F. Green. Can. Engr. May 16, '22.
High Level Concrete Bridge, Elora, Ont.* A. W. Connor. Can. Engr. May 23, '22.
Canada's Greatest Concrete Bridge.* Frank Barber. (From *The Contract Record and Engineering Review.*) Eng. & Contr. May 24, '22.
Arched Bridges of Wide Span.* F. von Emperger. (Paper read before Swedish Concrete Inst.) Eng. & Contr. May 31, '22.
Cantilever Arms on Aqueduct Trestle Allow Unobstructed Stream Flow.* R. A. Hill. Eng. N. R. June 1, '22.
Failure of Concrete Arch Bridge Due to Pier Washout.* Eng. N. R. June 8, '22.

f. Suspension Bridges. Transfer Bridges

The 705-Ft. Span Roundout Creek Suspension Bridge.* C. Y. Wang. Eng. & Contr. May 24, '22.

g. Swing, Bascule, Lift, Floating, Oscillating Bridges; Traveling Cranes

New Highway Bridge Over Bastiscan River, Que.* Edward Holgate. Can. Engr. May 16, '22.
Double-Track Spans Placed on Single-Track Piers.* Ry. Age May 27, '22.
Substructure, Johnson St. Bridge, Victoria, B. C.* F. W. Allwood. Can. Engr. June 6, '22.

h. Computations, Tests, etc.

Zur Frage der Grösse der Seitenpressungen der Eisenbahnfahrbetriebsmittel bei Berechnung eiserner Brückentragwerke.* (On the Question of the Magnitude of the Lateral Pressures of Locomotives in the Calculation of the Supporting Structure of Iron Bridges.) Franz Rautschka. Oest. Ing. Arch. Ver. Mar. 31, '22.

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F. Inland Waters

a. Natural Waterways (General Articles)

The St. Lawrence Seaway. W. L. Saunders. A. I. E. E. May, '22.

c. Regulation of Waterways—Volume of Discharge, Freshets, Floods, Soundings

Flood Problems: A Symposium.* J. G. Sullivan, Gerard H. Matthes, Nathan C. Grover, John R. Freeman, J. A. Ockerson, Roy N. Towl, Arthur P. Davis, C. E. Grunsky, and Charles H. Paul. Discussion, Morris Knowles, Harrison P. Eddy, J. Albert Holmes, D. W. Mead, Arthur O. Ridgway, J. B. Challies, George M. Lehman, W. H. Breithaupt, and Adolph F. Meyer. Am. Soc. C. E. May, '22.
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Fighting the Mississippi Flood at Oldtown, Arkansas.* L. R. Parmelee. Eng. N. R. June 8, '22.

d. Diverting Dams, Locks, Lifts, Elevators, Inclined Planes

Core Studies in the Hydraulic-Fill Dams of the Miami Conservancy District.* Discussion, George L. Dillman, Allen Hazen, H. F. Dunham, and Thomas H. Wiggin. Am. Soc. C. E. May, '22.
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h. Boats, Barges

Der Turboschlepper "Zürich".* (The Turbine Driven Tug *Zürich.*) Rud. Schätti. Schw. Bauz. Apr. 29, '22.

G. Maritime Works

b. Management and Protection of Coasts—Beaches—Dunes

Coast Preservation Works in British Guiana.* Herbert L. Vahey. Eng. & Contr. May 31, '22.

c. Vessels and Maritime Navigation. Lighthouses and Buoys. Various Signals

Longitudinal Strength of Cargo Vessels and Its Variation with Fullness of Form.* E. Leslie Champness. (Paper read before Inst. of Naval Architects.) Eng. Apr. 21, '22.
H. M. S. *Dreadnought.** J. H. Narbeth. (From Inst. of Naval Architects.) Engr. Apr. 28, '22.
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Dehnungsmessungen an Schiffskörpern.* (Measuring the Expansion of Ships.) Siemann. Ver. deu. Ing. Apr. 15, '22.

g. Dredges and Dredging—Force Pumps—Refloating and Removing Wrecks—Ice-Breakers

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h. Wharves. Mooring Buoys. Harbor Equipment

Large Hollow Concrete Blocks Form Dock Wall.* Eng. N. R. June 8, '22.

i. Harbors (General Articles)

The Port of Harwich and Parkeston Quay.* Dock and Harbour May, '22.
Seattle: The Great Modern Port on the Pacific.* G. F. Nichilson. Dock and Harbour May, '22.

j. Dockyard Machinery and Shipyards. Dry Docks

Mechanical Cargo Handling.* G. H. Rae. (Paper read before Liverpool Eng. Soc.) Dock and Harbour May, '22.

H. Railroads, Street and Interurban Railways, Automobiles, Aeronautics

a. Railroads

1. General Articles

Mexican Railways Prepared for Improved Business.* Charles W. Foss. Ry. Age Serial beginning May 6, '22.
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2. Location

Grade Reduction Increases Train Loads on Coal Road. Eng. N. R. June 8, '22.

3. Roadbed (Grading Construction Work)

Construction of the Road-Bed and of the Track. Henry. Int. Ry. Assoc. Apr., '22.

4. Track

Maintenance and Supervision of the Track. Earl Stimson. Int. Ry. Assoc. Apr., '22.
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5. Signals and Safety Apparatus

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6. Rolling Stock (Locomotives, Cars)

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7. Use of Electricity

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8. Stations. Engine Houses. Shops

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9. Technical and Commercial Use

Slow-Freight Traffic. U. Lamalle. Int. Ry. Assoc. Apr., '22.

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b. Special Railroads

1. Rack Railroads

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3. Narrow Gauge—Light Railways

Permanent Way on Mountain Railways.* George Ernest Lillie. Inst. C. E., 1920–21, Pt. 1.
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Special Methods of Traction on Light Railways. P. Baraghi. Int. Ry. Assoc. Apr., '22.

d. Street Railways, Elevated Railways, Subways

5. Rolling Stock

Les Autobus et les Tramways en Angleterre.* (Autobuses and Tramways in England.) Gen. Civ. Apr. 22, '22.

e. Automobiles

2. Internal Combustion Engine Automobiles

Tracteur Automobile Vigneron des Etablissements Delaunay-Belleville.* (Delaunay-Belleville Automobile Tractor for Vineyards.) G. Coupon. Gen. Civ. Apr. 15, '22.

f. Aeronautics

2. Dirigible Balloons

The problem of Mooring Airships.* Sci. Am. June, '22.

3. Aeroplanes

Messgeräte für Flugzeuge.* (Instruments for Airplanes.) E. Everling, and H. Koppe. Ver. deu. Ing. Apr. 1, '22.

I. Municipal Water-Works. Agricultural Engineering

a. General Articles

Cleveland Water System.* G. E. Flower. Am. W. W. Assoc. May, '22.
Water Works System at Richmond Hill, Ont.* G. H. Baker. Can. Engr. May 2, '22.

b. Hydrology-Water Resources

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c. Dams and Reservoirs

Siphon Spillways. Discussion, Fred A. Noetzli. Am. Soc. C. E. May, '22.
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d. Analysis and Purification of Water

Chlorine Tastes and Odors from Pipe Coating. E. J. Rowe. Am. W. W. Assoc. May, '22.
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Pumping Plant of New High Pressure Fire System at Buffalo, New York.* W. B. Powell. Mun. & Co. Eng. May, '22.
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Submerged Intake for 24-in. Pipe Placed Without Diver.* George W. Pracy. Eng. N. R. May 11, '22.
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f. Drainage of Land

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Pumping Plants for Land Drainage. L. C. Craig. (Paper read before National Drainage Congress.) Can. Eng. May 23, '22.
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Central Repair Shop for Philadelphia Water-Works.* John M. Broggini. Eng. N. R. May 11, '22.

J. Sewerage. Sewage and Refuse Disposal

a. Sewers and Drains

Plain Concrete Sewer Acts as Beam After Washout.* Orrin E. Stanley. Eng. N. R. Apr. 27, '22.
Limit of Roof Connections to Separate Sewage Systems.* John P. Wentworth. Eng. N. R. June 1, '22.

b. Sewage Disposal. Purification

Characteristics of Some Connecticut Sludges.* J. Frederick Jackson and Joseph Doman. Bost. Soc. C. E. Feb., '22.
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Features of Sewage Disposal Plant at Randolph, Neb.* Keyes C. Gaynor. Mun. & Co. Eng. May, '22.
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c. Refuse Disposal

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K. Heat Engines.

a. Steam Engines. Boilers

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b. Gas and Oil Engines

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L. Electricity

a. Production of Electricity

2. Magneto and Dynamo—Electric Machines
Temperature Limits in Large Machines.* Philip Torchio. A. I. E. E. June, '22.

b. Distribution and Transmission of Electricity

1. Power Plants
Boiler-Room Performance and Practice of the Colfax Station, Duquesne Light Company.* C. W. E. Clarke. Mech. Eng. May, '22.
New Hell Gate Power Station.* Power May 2, '22.
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Battle Creek Steam Plant of Consumers Power Company.* W. W. Tefft. Power June 6, '22.
3. Distribution and Wiring of Electricity
Rating of Cables in Relation to Voltage. (Subcommittee on Wires and Cables of the Standards Committee.) A. I. E. E. June, '22.
On the Minimum Stress Theory of Cable Breakdowns.* Donald M. Simons. A. I. E. E. June, '22.
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4. Measures—Meters—Rate Making
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5. Transformers and Converters
Triple Harmonics in Transformers.* G. Faccioli.* A. I. E. E. May, '22.
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d. Mechanical Uses of Electricity

1. Electric Motors
A Method of Determining Resultant Input from Individual Duty Cycles and of Determining Temperature Rating.* Bassett Jones. A. I. E. E. May, '22.

e. Electro-Chemistry and Electrometallurgy

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f. Signals and Communication

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AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852.

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications.

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Vol. XLVIII. AUGUST, 1922. No. 6.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

ADDRESS AT THE ANNUAL CONVENTION, HOTEL WENTWORTH, NEAR PORTSMOUTH, N. H., JUNE 21ST, 1922.

BY JOHN R. FREEMAN,* PRESIDENT, AM. SOC. C. E.

The By-laws of the Society require an address by the President at the Annual Convention. In nearly all scientific societies, the address of the President comes at the close of his term, which seems a more appropriate time. I awoke to this time of delivery too late to permit the development of my chief topic as I have desired. Before deciding on this topic and in order to learn the traditional scope and treatment, I read all the Presidential Addresses of the past 25 or 30 years. I found them mostly devoted to one of three subjects: (1) The Society; (2) the status and relations of the Engineer to the Public; and (3) a historical review of progress in that line of engineering to which the speaker had chiefly devoted his professional life.

While thus studying the proper topic and scope for a Presidential Address, my thoughts have been drawn in two directions: One, Progress in the Development of this Society and Its Possibilities for Greater Usefulness, and the other the Development of Hydraulic Science. I am particularly drawn to this topic, because it is now almost fifty years to a day since I began as a Junior Assistant Engineer in the office of the Water Power Company, at Lawrence, Mass., and my professional life has been chiefly devoted to Hydraulic Engineering.

Before proceeding with this second topic, I cannot, following forty years of membership in the Society, many years of membership in various other engineering and scientific societies, and five months in the closer view given by my present office, refrain from saying something about The Society and Its Progress.

As I recall my three years of service on the Board of Direction about 25 years ago, and compare the technical activities then and now, I find that the time and effort now given by the individual members of the Board toward the development of the Society has been vastly increased. Then, the Board could

* Cons. Hydraulic Engr., Providence, R. I.

California miners, and "through our failures we achieve success". Then Science comes and shows the way to economy, reducing wasteful cross-sections, combining experiences, deducing theory from successful practice, and giving confidence for projecting structures to longer spans, higher pressures, and new lines of attack. Textbooks and published data often lag far behind the information collected here and there by some one under stress of circumstances. The *Proceedings* and *Transactions* of Engineering Societies provide convenient places in which to record these forward steps.

One great service of the *Proceedings* of technical societies is the collection, preservation, and early dissemination of these experiences and newly discovered facts, so that they may be available to engineers and to writers of textbooks.

Our Society machinery does not yet seem particularly well organized for scanning the horizon, discovering, and systematically bringing foward and publishing these new data. The busy worker has his hours so full of responsibilities that commonly pressure must be brought on him to sacrifice his time to prepare a paper, through the appeal of rendering service to others. Some of the best papers of the past year have been thus obtained, more can be done in this line and Object No. 1 of the Constitution thus better attained.

The Engineering Foundation was established to aid in advancing Applied Science, and to aid in developing new data, by a far-seeing engineer who intended his own gift to be merely a nucleus to which others by adding might testify in a substantial way to the help they had received from association in the Engineering Societies and the researches of their predecessors; or, if they had prospered, might pay in like manner a part of their debt to the Profession.

Cannot our Society take a more active part in making this great idea bear more fruit, both in increment to this fund and in adding to data for the practical engineer? Would it not show a finer spirit of appreciation toward those who build up this Foundation fund, if every dollar of its income from endowment was devoted to its main purposes, while the four National Societies took on themselves the whole expense of its administration?

On the second topic, "Professional Improvement", and on the third, "Encouragement of Intercourse", does not our present opportunity for doing more lie chiefly in a stronger and better organized support for each of the Local Sections? For the Board of Direction simply to frame some permissive rules for the Sections and then to give back $1 per year of the $20, or more, of dues collected, is not enough attention by the Parent Society. The Student Chapters also may well be given much more attention, and a strong effort put into the active development of the newly provided for Professional Sections within the Parent Society.

On this topic of intercourse, I take this occasion to express my regret at my inability to accept many of the hospitable invitations to address Local Sections and Student Chapters. I have gladly done so, as far as practicable, but with 34 Local Sections and 45 Student Chapters, it is obvious that some new means of showing proper attention from the home office to these scattered, distant bodies should be devised.

These second and third ideals of the Constitution—Professional Improvement and Intercourse—could be better satisfied by a larger membership. In his

Presidential Address,* eight years ago, Hunter McDonald, Past-President, Am. Soc. C. E., stated that the engineering development of the United States was then such that outside our Society there were three or four times as many qualified by the standards for membership, as there were inside the Society. Most of us who have broad contacts with what is going on in the United States, will on reflection agree with him, and agree that all three of the first aims of the Constitution, "Advancement of Science", "Professional Improvement of Members", and "Intercourse among Engineers", will be better satisfied when more of those now outside are quietly made to see that they should be inside the Society; not so much for what each can receive, as for what all can give in the maintenance of professional ideals.

By no means should the requirements for admission be lowered or less rigidly observed. The Constitution and By-laws make plain the intention to restrict membership to the specially educated, skilled, and supervising class and to young men who are educating themselves for high responsibilities. We owe it to ourselves and to the public to maintain Engineering as one of the learned professions.

All four of the objectives of the Constitution of this Society can be promoted through continually improving the quality of the publications. Civil Engineering presents the broadest field and opportunity of any branch of engineering for valuable papers and discussion, because of the scale of work, the variety of its field, and its many and broad public relations. A large proportion of the membership is in the direct service of the public, as City engineers, State engineers, public health administrators, railway administrators, and in various other branches of public service. Therefore, it is not strange that, in the course of the present year (1922), the Society is publishing a greater number of technical papers and more square inches of discussion of technical papers than any one of the other three National Societies (although less than the National Society of Chemical Engineers and Chemists which I hope will some time be in the United Engineering Society group).

While thus fulfilling the specifications of the Constitution, does not our monthly publication now partake too exclusively of the character of a cold storage warehouse, filled with valuable material, to some of which each member will certainly want to refer in the future, but not all of which is particularly interesting just now, particularly when one is a thousand miles away from the Engineers' Club.

The quality and the tonnage now going into this storage warehouse are admirable, but cannot we work in between these valuable papers more pages of immediate human interest to the junior members and to the thousands of distant members who pay their dues, 90% of whom can neither attend an Annual Convention nor enter the Society House in New York City.

Cannot the *Proceedings* (or preferably perhaps an intermediate journal) carry more pages about what is going on just now in the engineering world, more of its inspiring story of current general scientific research, better book reviews by eminent practitioners, or teachers, which will give the young engineer a better guide to what he should add to his working library, out of

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* *Transactions*, Am. Soc. C. E., Vol. LXXVII (1914), p. 1737.

his modest salary? Would it not be well to let each issue carry a few small half-tones and biographical sketches of engineers prominent in notable works of the day, thus adding more of the touch of human interest and should not we find means for sending out better abstracts of current technical literature?

If the present ten issues per year become too bulky, split the material into twelve or twenty-six issues. Due regard for the distant member suggests that the issue should not be suspended two months in summer.

Such improvements, as suggested, cannot all be made at once, and to live up to present-day opportunities and to provide the right personnel for additional work will require more money than is carried in the present budget. How to obtain this is another pressing and important question.

I will now proceed to the second topic, Hydraulic Science, and present some notes on its development and some suggestions of further development.

Old books on Science are always interesting and suggestive. I have found this true of Hydraulic Science and as I have taken books from the shelves of ancient libraries, I have found that although the art of the Hydraulic Engineer is old, his science is young, and some parts of it now appear to be in a state of arrested development. If this development is lagging, let us join in starting something!

Progress in Hydraulic Science

"Irrigation is the oldest branch of Applied Science in the world,"* says Sir William Willcocks, famed for hydraulic works and studies in Egypt and the Holy Land. One of the most remarkable pieces of ancient art that has been preserved in all the world, is a head, beautifully sculptured in obsidian, of the Egyptian king who completed Lake Moeris, greater than any irrigation reservoir since built, more than 4 000 years ago.

Thus, when the Mechanical Engineer, in pride of ancient lineage, points to Tubal-Cain or to the Artificer in Iron whom the wise Solomon seated at his throne, the Hydraulic Engineer may point to the important work of his ancestor who had charge of the canals in the Garden of Eden. For Sir William also says: "The events recorded in the early chapters of Genesis had their origin in a rainless land where life depended upon irrigation." He quotes from the second chapter of Genesis: "Out of Eden came a river which watered a garden", and says that, in the course of his explorations, he has discovered the precise spot. Also, he tells us how these rivers in the Holy Land have eroded their beds and impaired their possibilities for service since Biblical days.*

Speaking precisely, it was only an Art and not a Science by which, in those early days, water was regulated as it flowed down hill or was guided as it sought its level. The Arts of controlling water were pre-historic, but Hydraulic Science did not have its birth until thousands of years after the dawn of history, or until about 300 years ago. Its birthplace was along the rivers of Italy.

* "From the Garden of Eden to the Crossing of Jordan", by *Sir* William Willcocks, Spon & Chamberlain, New York.

Until very recently, all the Constructive Arts have been far ahead of their Sciences, as we now differentiate the terms, Art and Science, and most of the inventors and great builders of the past have not been scientists. The special mission of Science—the organization of knowledge, the discovery of natural law, and its expressions in formulas—has been to bring safety and economy into the Constructive Arts, and only very recently, and mainly in the new fields of Chemistry and Electricity, have Science and Mathematics yet accomplished very much in pointing the way to progress in the arts.

Very curiously, the old Roman, with all his skill in architecture and aqueduct building, seems to have had no conception of measuring velocity as a factor in quantity of flowing water, because he had no instrument with which to count seconds; therefore, he measured the discharge of his aqueducts in "quinaria", a sort of ancient "miner's inch",* of double the California quantity, determined by the diameter of a short outlet tube. His state of mind was much the same as that of the practical man of to-day who says, "as much water as a 6-in. pipe will deliver", or that of the country lawyers who drafted certain old water-power leases in which the water right was measured by the diameter of the penstock.

More than 250 years of slow earnest painstaking work by the greatest engineers and scientists of the Middle Ages was required to work out the simple fundamental formula, $V = \sqrt{2\,g\,h}$. The writings of Vitruvius, Frontinus, and even those of that greatest of all men of inventive genius, Leonardo da Vinci, reflect few, if any, glimmerings of exact science in the laws of flowing water, and it was not until about 300 years ago that a pupil of Galileo worked out his formula that the discharge from an orifice varied as the square root of the head. It was not until about 125 years later, in 1738, that the mathematician, Bernoulli, put the gravity factor into this formula and gave engineers the present fundamental hydraulic formula of $V = \sqrt{2\,g\,h}$, with which Hydraulic Science really began.

Tennyson says: "Science moves but slowly, slowly; creeping on from point to point", and Hydraulic Science moved very slowly and almost not at all until about 200 years ago, when there came a beginning of precise observation and experiment, and a development of Hydraulic Science, in both Italy and France. 150 years ago, the fundamental formula for the flow of water in canals, aqueducts, and pipes, that is in general use to-day (the Chezy formula), was developed at the water-works of Versailles; and, about 100 years ago, the French engineers had developed the mathematics of hydraulics to nearly the point where they stand to-day. In the next 50 years, there was much progress, but this has since lagged and it is now high time we gave Hydraulic Science a new impetus.

Eighty-three years ago, fresh from his studies at the French School of Bridges and Roads, the late Charles S. Storrow, Hon. M. Am. Soc. C. E., of Boston, Mass., the best educated American engineer of his generation, wrote "A Treatise on Water-Works" which at that time was by far the best in the English language and was so clear, so complete, and so condensed, that it might serve as

* A "quinaria" was probably equivalent to about 2 miner's inches, or to 5 000 to 6 000 U. S. gal. per 24 hours.

a college textbook to-day and lead no one into serious error by its methods of computing flow through orifices and pipes or over weirs. His introductory chapter contains one of the best brief historical reviews of the development of Hydraulic Science that has yet been written, and his earnest plea—that engineers in charge of hydraulic work add to experimental knowledge—continues worthy of repetition to-day.

It was from 60 to 70 years ago that Francis made the greater part of his famous Lowell hydraulic experiments and published his book thereon, which is a classic in clear description and in detailing precision of measurement. He was the first in the world to design his experimental hydraulic apparatus of a size that could deal with full-sized specimens. Until his time, the orifices, weirs, and conduits used by the scientists to develop and prove their formulas were but very few inches in diameter, and the fact that they got a fair degree of accuracy should give confidence in the laws of hydraulic similitude when we seek the laws of river flow in a laboratory. Francis' formula for discharge over weirs, his methods of testing turbines, and his methods for measurements of the discharge in canals by floats, remain standards for precise work to-day.

It was from 60 to 70 years ago that Humphreys and Abbot wrote their great book on the "Physics and Hydraulics of the Mississippi".

Although the past half century has been a period of marvellous development for all kinds of structures within the field of Hydraulic Engineering, and dams, aqueducts, municipal supplies, power developments, reclamation works, and canals have reached really wonderful dimensions in many parts of the world, particularly in America, experiments and systematic observations for increasing knowledge in important branches of the Science of Hydraulics have lagged behind the development of the art.* In the important field of training rivers, erosion of river beds, and in laws governing the deposition and transportation of sediments as affecting problems of relief from floods† this branch of Science has mostly slumbered, except at one or two small laboratories in Germany, of which I will speak later, although Fargue, in France, and Engels, in Germany, and a few others, have worked diligently to formulate observations on the fixing of locations of gravel bars on rivers of the European types, for the benefit of navigation. For example, the six rules of Fargue chiefly relate to stabilizing a navigation channel, to keeping the shoals so placed that the pilot will know where they are.

Most of the studies and books on river training have had navigation as their aim, while in these later years protection against floods and reclamation of fertile lands have become of relatively greater importance.

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* Most of the college textbooks on Hydraulics fail to show that even the root given in the fundamental Chezy formula is probably wrong and should be written as ⅔ or ¾ instead of ½, the correction being now made in the variable coefficient. They give little warning that ordinary types of current meters in disturbed water may show velocities far from the truth. Their back-water formulas are not readily applicable to real rivers. They give no intimation of the twisting currents often found in circular penstocks and fail to note that the curve of distribution of velocity does not follow the parabolic law near the conduit wall in pipes or in river beds, but is greatly retarded. They say almost nothing about precautions for accuracy in application of formulas, etc., etc.

† The erosion and transportation of sediment probably has been studied more by English engineers on the great irrigation canals in India than anywhere else in the world, but their knowledge appears far from being yet organized into Science. A good résumé may be found in Buckley's "Irrigation Pocket Book" (Spon & Chamberlain, 1920).

What we now chiefly need is to find out how to control the sediments and improve the carrying capacity of rivers to the sea, so that with all possible speed and facility the main trunk will take away the water delivered into it by the branches.

We need to find out how best to make a river dig its bed deeper, instead of obstructing itself by rolling up its gravel bars into dams at every "cross-over" in the early stages of a flood. The late Professor J. B. Johnson, M. Am. Soc. C. E., stated the case well in 1884, in the *Proceedings* of the American Association for the Advancement of Science, in the language of a former Secretary of the Mississippi River Commission: "The first work of a flood is to impede its own discharge and the impediment outlasts the flood." Johnson cited observations at Columbus, Ky., comparing heights on the river gauge when the river was rising, with heights for the same number of cubic feet per second (1 100 000) on a falling stage, showing an average increase of 2.1 ft., and a total increase in flood height of 5.5 ft., due to gravel rolled up on to the bars.

This stagnation and need for a new departure in hydraulic experimentation and science was forced upon my attention, a few years ago, when I was reviewing the literature of river training, in preparation for my studies in China, and recently has been brought to my attention during a recent tour of inspection, first along the Missouri River, near Omaha, Nebr., to inspect those "Retards"* shown by Roy N. Towl, M. Am. Soc. C. E., in moving pictures at the Dayton meeting of this Society on April 5th, 1922; which "Retards" are permeable elastic spur-dikes, built of trees, for training the river to avoid bridge abutments and to turn it away from eroding valuable farm lands; and it was still more forcibly impressed upon me only a few weeks ago when I inspected the threatened and the flooded regions along the Lower Mississippi at many points from Memphis, Tenn., to below New Orleans, La., including the crevasses near Ferriday and Poydras, the near crevasse at Tunica, and the threatening of a crevasse at Stanton, La.

Since that inspection, I have been reading the story of the Mississippi levees and jetties and proposed spillways in the library of river and harbor literature collected by the late Elmer L. Corthell, Past-President, Am. Soc. C. E., and as I have learned more details of the many controversies and of the diametrically opposite opinions of high authorities about river training, protection against floods, and about maintaining channels for navigation, which controversies have centered around the outlet of the Mississippi and certain harbors of the Gulf States, and the divergent views that prevail to-day in New Orleans about safe-guarding the future of the city, both as to floods and as to navigation, I have become more and more impressed with the idea that this branch of Hydraulic Science in particular is still in the stage of argument and opinion, rather than that of precise observation and determination of facts; and that the science of current control, particularly in rivers carrying large loads of sediment and flowing over beds of deep alluvium,

* A brief description of these retards is given in the paper by Mr. Towl, entitled, "Missouri River Bank Protection at Omaha, Nebraska", *Proceedings*, Am. Soc. C. E., May, 1922, p. 1185.

is now very much where chemistry was before the universal use of the balance, or where electricity stood prior to the centimeter-gramme-second units.

On the Lower Mississippi, they have just been having the highest water ever known, and no one can appreciate the frightful conditions of threatened and ruined homes, of tens of thousands of square miles of the most fertile land in the United States, worth, literally, hundreds of millions of dollars, threatened by inundation and by the loss of a year's crops, until he has been on the ground during high water and has seen this mighty river, ½ mile wide, 100 ft. deep, 50 ft. above its normal stage, rushing along with its surface within 6 in. of the top of thin soft earth dikes, from 12 to 18 ft. high, and here and there threatening to cut through them by a new eddy or swirl of the current; or until he has seen the temporary protective works hastily built by thousands whose homes and properties were threatened.

There are two distinct problems along the many miles of levees: One, that of designing and building a strong impervious dike to a proper height; the other, that of guiding and controlling the direction of the swift current so that it will not undermine and cut into and rupture the dike or "levee". One who is rash enough to risk an encounter with the authorities, American, French, and German, many venture to ask if there is not a third problem, namely, that of training the river to dig its bed deeper; and in New Orleans substantial citizens are asking that a fourth problem, many years old, that of spillways through the levees, be again considered.

Revetment of all the hundreds of miles of threatened banks against possibility of erosion is hopelessly beyond limits of expenditure. Advances in both the Art and the Science are needed.

For ten years past, I have been thinking of the benefits that might come from a hydraulic laboratory, built on a large scale, in which sundry important observations could be made, and nine years ago, I visited the new Flussbau Laboratorium of the Technishe Hochschule at Dresden, Germany. Three years ago, I urged the value of such a laboratory on a group of members of the Society gathered at lunch in San Francisco, Calif., urging that, if established at their great University of California, it would contribute greatly to the economic solution of some of the problems of the Sacramento River and of the problems presented by some of the torrential streams that at times rush down the Pacific delta cones.

On several occasions, I have suggested the value of such a laboratory *somewhere* in the United States, and what I have seen and read during the past few weeks has led me to believe that *now is the time* to urge the importance of immediately constructing a National Hydraulic Laboratory, on a larger scale, in some locality where it will be in a scientific atmosphere (for, in addition to many simple matters of experiment and observation, there are some very obscure phenomena of intricate hydrodynamics, colloidal physics, and other abstruse matters to be considered), which shall be at the service of whatever branch of the Government that may need it. First, for a season, say, in the service of the River and Harbor Engineers; next, perhaps, of the Hydrographic Branch of the U. S. Geological Survey; next, possibly, for some months, in the hands of the U. S. Reclamation Service; and, next,

perhaps, serving the Department of Agriculture; and sometimes serving a special purpose outside the Government service. Such a laboratory, operated in close parallel to studies on the real river, can be made to give a new impetus to several extremely important branches of Hydraulic Science, and give precise data which we lack in important fields. More about an hydraulic laboratory will be said later.

Resuming the story of progress, the Outlines of History of Hydraulic Science must be greatly condensed in an address of this kind, because to tell all the development that is of interest to an hydraulic engineer, would require some hundreds of pages.

Commonly, we forget how young all engineering science is. In most branches, it began its rapid development only about 100 years ago, or at most, 150 years, and followed close upon the greatest of all of man's inventions, the manufacture of power by the steam engine. It is hard for me to realize that my own engineering experience of 50 years covers one-third (one almost might say one-half) of the whole history of these great engineering activities, and that I knew personally the chief engineer of the earliest railroad in New England and the author of the earliest American book on Hydraulics, and that the greatest public work constructed by our National Government up to 90 years ago was the stone dry dock at the Charlestown Navy Yard, built from designs of Mr. Loammi Baldwin.

Although the Science is young, its Arts are old. The art of irrigation was highly developed in pre-historic times in many lands, in Egypt, Chaldea, India, China, and other parts of the earth. At the dawn of history, the flood waters of the Nile were regulated and stored for irrigation in Lake Moeris—far larger than any present-day storage reservoir—into which the waters of the Nile were led by the Canal of Joseph. In Szechuan, China, the present irrigation channels, watering many thousands of acres, are said to have been admirably designed and regulated, some thousands of years ago, by an engineer who worked out matters in great detail, set monuments for regulating the depth to which water might flow, and prescribed good rules of operation that are said to be still faithfully observed.

The arts of river control and canalization also received attention in those ancient days. Back in the half legendary days, about 4 000 years ago, China's most famous hydraulic engineer, the great Yu, is said to have successfully regulated rivers by dikes, guiding them into new channels, so that the people got along fairly well for 1 000 years, while his rules were followed. Many temples were built in his honor. The Grand Canal of China was built in part 2 400 years ago.

The Suez Canal retraces a small canal of many hundred years ago. There was a canal dug from the Nile to the Red Sea in the reign of one of the Pharaohs, more than 1 450 years before the Christian era. The "fresh-water canal" used by the French engineers of 1863 to convey fresh water from Cairo to Suez had been in use for 2 500 years. Along the Tigris and Euphrates, large canals were in use for irrigation and for boats, 350 years before the Christian era, the ruins of which show them to have required much engineering skill.

In Greece, at Corinth, the American School of Archæology has excavated the remains of ancient fountains and conduits, which, as I inspected them, gave me much respect for the skill of the workmen of 2 000 years ago; but it was art and architecture that were in evidence rather than engineering design. In many places in the Old World one finds remains of wonderful aqueducts, tunnels, and foundations built by the Romans about 2 000 years ago; and to me the most beautiful of all their structures, more beautiful than temple or palace, amphitheatre or forum, is that aqueduct bridge, the Pont du Garde, near Nismes, France.

Vitruvius, in his ten books on Architecture, written nearly 2 000 years ago, devotes the eighth book to Water Supply, but almost the only engineering data in its many pages of forgotten lore are some directions for constructing an accurate leveling instrument, the rule that aqueducts should not slope at a less gradient than 1 part vertical to 4 800 in length, or slightly less than 1 ft. per mile, and rules for the weights of lead water pipes. Caution is given about providing air vents and suggestions for laying clay water pipe with tongued ends, perhaps somewhat like that now made near Akron, Ohio. Vitruvius was wise in his sanitary precautions and strongly warns against poisoning from water conveyed in lead pipes, giving preference to pipes of clay; but in spite of its author's manifest effort to tell all that was worth knowing, it is really surprising to see how little this eighth book of Vitruvius contains of what we would call scientific information.

About 250 B. C., Archimedes, the great Greek scientist of ancient Syracuse, invented the screw pump, discoursed on principles of flotation of solids, detected spurious gold by determining its specific gravity in water, and is said to have discovered fundamental principles about the flow of water, but just what these were, I have not found recorded. Vitruvius quotes him as knowing that the earth was round and that a broad water surface had a curvature corresponding to its radius.

Julius Frontinus, Water Commissioner of Rome, about 70 A. D., left in his writings an admirable account of the aqueducts of Rome and their management. This account has been made available in English by Clemens Herschel, Past-President Am. Soc. C. E., in his excellent volume,* in which the translation of the original treatise is supplemented with a great deal of Mr. Herschel's own analysis of the ancient records, by a brief history of the development of early Hydraulic Science, and by many illustrations of appliances used by the Romans in distributing their domestic water supply. Frontinus seems to have been a faithful administrator rather than an engineer, but he compiled many notes and records, and had there been extant in his days any Hydraulic Science, beyond the simple facts that water would flow at about the right speed down an aqueduct having a declivity of about 1 ft. or 2 ft. per mile, and that it could be metered in a common-sense way by the area of the stream, or by the area of pipes leading out from the aqueduct, he would have told us all about it.

Outside the books of Vitruvius and Frontinus, as far as I have been able to learn, hardly anything can be found written on Hydraulics until about 425 years ago, when Leonardo da Vinci, engineer, artist, architect, poet,

* "Frontinus and His II Books on the Water Supply of the City of Rome, A. D. 97."

sculptor, and foremost of experimenters—greatest genius of all time—wrote on the "Motion and Measurement of Water" and invented, or first constructed, the navigation lock, which gave a new impetus to canal building. Some years ago, I visited the site of this first lock, as one visits a shrine. Although water still runs down the canal, it now serves to generate electricity for Milan.

With all his genius and his art, and his wonderful skill in mechanical invention, Leonardo did not add so very much to Hydraulic Science, and, after his time, it seems to have slumbered for 100 years, until the days of Galileo and his pupils, Torricelli and Castelli, each of whom was a real scientist and began the development of precision of measurement and the systematic arrangement of facts expressed by mathematical laws.

The experiments of Galileo on efflux appear to have been begun in efforts to construct a water-clock, measuring time by the flow of water through an orifice, which should be a more accurate timepiece.

It was Castelli, working under the direction of Pope Urban VIII, in 1628, who appears to have first published a treatise on rivers, and he appears to have been also the first to introduce velocity as a factor in measuring the discharge of rivers; but he supposed wrongly that discharge varied *directly* as the head.

In 1643, Torricelli discovered that water issuing from an orifice followed the law of falling bodies, on which his master, Galileo, had experimented at the Tower of Pisa; but although he got the idea of "the square root of h" all right, it was not until nearly 100 years later that the factor "$2g$", was put into the equation by mathematicians. Torricelli appears to have been the first who argued that the acceleration of rivers was due to the slope down which they ran.

Forty years later than Torricelli, in 1684, the French physicist, Mariotte, gave a new impetus to Hydraulics by his observations on flow from tubes and orifices, and he also wrote a treatise on the movement of water.

In Italy, there was great need to study means of relief from the floods of torrential mountain streams that brought not only floods, but also débris and sediment that clogged the river beds and added to the woes of the people, particularly along the lowlands of the River Po. Therefore, it is not strange that river science had its birth in Italy.

In 1697, Guglielmini published the first part of an elaborate work, "Della Natura de Fiumi", the second part of which was published in 1712, after his death. He appears to have been one of the earliest scientists to grasp fundamental principles and made many contributions to Hydraulic Science, probably more than all the others who had preceded him, but he went sadly astray about a few of them, for example, in his notion of the distribution of velocity at various depths. His work is spoken of very kindly by authors of a century later. Undoubtedly, he was the pioneer in River Hydraulics and the old quotations from his works show that he started several important questions that are not settled to-day, and to answer which we need a National Hydraulic Laboratory.

Mathematical science by this time was well expressed in algebraic equations, also the application of calculus to Science was receiving great development, and the great mathematicians seem to have been fascinated with the problems of

flowing water, but made a bad mess of trying to devise their laws from *a priori* reasoning instead of by observation in field or laboratory. Sir Isaac Newton, the greatest of all these mathematicians, tried his hand at formulating laws about flowing water, but found no great success in this field, although he developed some beautiful equations in the "Principia", published about 1714. Soon after 1714, there came a rapid succession of authors on Hydraulics.

In 1718, Marcus Paulini experimented on the discharge through orifices and discovered that it could be increased by adding a short tube. Frontinus had previously stated that this principle was known in Rome, and that thrifty Roman water takers had applied it to increasing the discharge from the aqueduct into their premises by adding an enlarged tube to the official nozzle.

In 1730, Pitot, member of the French Academy of Science, invented the Pitot tube which in more elaborate form we use to-day, for measuring velocity and disproved Guglielmini's ideas on the distribution of river velocities at various depths, although his precision of measurement was crude.

In 1732, experiments made on the flow of water in the pipes leading to the Versailles Fountains, were reported to the French Academy.

In 1738, Daniel Bernoulli, and, in 1742, John Bernoulli, father and son, began the establishment of sound mathematical theory as a basis of Hydraulic Science and developed the doctrine of living force.

In 1743-52, d'Alembert, another great mathematical physicist, made important contributions.

In 1764, Paul Frisi, Professor of Mathematics at the University of Milan, wrote his celebrated treatise on the "Nature of Torrents", quoting largely from Guglielmini's observations and giving proof in many ways of being an earnest seeker after truth. Other Italian writers on the flow of water flourished about this time, their interest being aroused by the flood problems of the Po and other Italian rivers. In 1765, Lechhi, of Milan, also wrote an elaborate treatise.

In 1768-71, Euler, the great mathematician, published, at St. Petersburg, a treatise in which he attacked the problem of the flow of water and made useful mathematical contributions.

Up to about this time, or as recently as 150 years ago, the sum total of contributions to theory, other than the one formula for efflux, $V = \sqrt{2 g h}$, was of little practical importance, because of the lack of care to test theory by experiment and from the lack of precision in measurement; but from about 1764 to 1774, the experimental era was inaugurated, and both in Italy and in France the hydraulicians had reached the conclusion that formulas must come from experiment and not from pure mathematics. Within the following hundred years, the science was developed nearly to where it stands to-day.

In 1775, Chezy, as already stated, gave us his extremely valuable formula for the flow in conduits, but without much discrimination as to the effect of roughness of the wetted surface.

In 1782, Belidor wrote a monumental work on hydraulic architecture, copies of which I have found in three of the early American engineering libraries.

In 1784, the Academy at Toulouse, France, reported experiments on the discharge of orifices and some notes on the junction and separation of rivers.

In 1779-86, Dubuat reported his results of ten years' reports and experiments. Some of his data on the transportation of débris are still reported in textbooks of to-day, as if his data were of practical value—which they are not, because of having been obtained by experiments on the effect of a current of water in moving sand and pebbles lying loosely on the smooth bottom of a little wooden trough only 18 in. wide and less than 1 ft. deep.

I would not leave the impression that I have laboriously read the works of all of the previously named authors, but from time to time I have turned the pages of many of them and have found much of interest in tracing parts of this history in certain old libraries, particularly, in the Locks and Canals Library at Lowell, collected mostly about 75 years ago by the late James B. Francis, Past-President, Am. Soc. C. E., and in the remarkable library of Mr. Loammi Baldwin, who has been called "The Father of Civil Engineering in America", the collection of which was begun about 100 years ago. Baldwin's library was doubtless the best possessed by any engineer in America in his day, and it is extremely interesting as illustrating the breadth of culture of this early engineer. It is particularly rich in the French hydraulic works of 100 years ago, and contains also a few books in the Italian language, notably a treatise, in three thick volumes, on the motion of water, published at Parma in 1766, the second volume of which is entitled "Della Natura d'Fiumi: Trattato Fisico Matematico dell Dottore Dominico Guglielmini", etc.

The Baldwin Library also contains a copy of "Noveaux Principles d'Hydraulique Appliques à tous Objets d'Utilite et particulierment aux Riviéres", published in 1687. It is interesting to note this author's good words for Guglielmini, the author on river hydraulics of nearly a century before. On page 3 of its Introduction, this book contains a very interesting reference to Galileo's opposition to straightening the Bisenzio, and his seven principles, derived *a priori,* in opposition to Bartolotti, who proposed straightening the river. The author states that "Galileo had the misfortune of making his opinion prevail in spite of the truth." (This remark reads like some of those made 235 years later in the controversies about the Mississippi.)

The Baldwin Library contains also a copy of the work, "Recherches sur la Construction la plus Avantageuse des Digues", a prize essay published by the Toulouse Academy, written by Citoyens Boussut et Viallet in 1772, which, in certain of its diagrams, illustrates that groynes and retards for the protection of river shores had been used more than 150 years ago.

In this library is also to be found a copy of De Prony's work, of 1822, on the Pontine Marshes, which he had studied as member of a commission in 1810, as well as a copy of "Essai sur la Theorie des Torrens et de Riviéres, par Citoyen Fabre, Ingenieur en Chef des Ponts et Chaussées", published in 1817; also a book of 280 pages, entitled "Les Moyens les plus Simples d'en Empecher les Ravages d'en Retrecir le Lit et d'en Faciliter la Navigation" ("The Most Simple Means of Restraining the Ravages of Rivers, of Narrowing or Straightening the Bed, and of Facilitating Navigation").

The library also contains the work of MM. Poncelet et Lesbros on the discharge of orifices, published in 1832. It contains many other books of interest to an engineer, showing the state of these arts and sciences 100 years ago.

Incidentally, it may be of interest to remark, as showing the broad culture of "The Father of Civil Engineering in America", that in addition to many scientific works in English and French, and a few in Italian, Mr. Baldwin's library was rich in classic literature and in works on Natural History, for which apparently he spared no expense, for we find here an original set of Audubon's celebrated volumes, "Birds of America", with hand-colored plates, which was published at $1 000 per copy. The scientific part of the Baldwin Library is now at the Massachusetts Institute of Technology, but the parts relating to general literature and Natural History are still in the old Colonial mansion of the Baldwin family at North Woburn, Mass.

A copy of the celebrated treatise of Paul Frisi, on "Torrents", may be found in the Library of Brown University. This English translation is of interest, having been made more than 100 years ago by an English engineer officer for the use of the English engineers in India in their early days of developing the vast Indian systems of irrigation. Few in America appreciate the present magnitude of those Indian irrigation works or the early day at which England began this beneficent work in India. This conscientious engineer-translator visited Italy to check up the general accuracy of the statements in the original work. The book was dedicated to Warren Hastings. It is a beautiful sample of the printer's art of 100 years ago, contains many references to the investigators who had gone before, and raises several important questions about which there is still controversy, such, for example, as the raising of river beds by diking their floods. There are chapters on the subsidence of the sea coast, and on deposits of sediment, and experimental proof that gravel stones could not be ground down into sand during their passage down the whole length of a river, wherefore those brought in by mountain torrents must accumulate and raise the bed of the river near the foot of its steeper slopes; and on the raising of certain up-stream sections of the beds of Italian rivers within the historic period, he presents much proof. He also shows that the débris dams of California were anticipated several hundred years by those of Italy, which were not always successful, etc. All of this shows Paul Frisi to have been such an earnest seeker for scientific truth that we wonder he could not find more of it. This book of 168 years ago details controversies between the highest authorities over the flood problem of the Po and other Italian rivers, which very much resemble those that have raged up and down the Lower Mississippi and the Sacramento and, thence, have spread to Washington, during the past 50 years, and are still unsettled. They were then, 168 years ago, violently discussing the efficacy of cutting spillways in the dikes to take off their floods, somewhat as at New Orleans to-day.

From the accounts of Pliny and Tacitus, they seem to have been discussing and trying out the same ideas in Rome (with poor success), 1 600 years before. Frisi quotes Tacitus as recording a dictum of the Roman Senate concerning straightening the Tiber, "Nature has known how to provide for our wants

much better than Art in assigning to rivers those courses, boundaries, and limits, which are most apposite". This reminds one of those recent authors who oppose training rivers to straight courses "because Nature always guides them on curves", without reflecting that Nature's purpose was largely that of delta-building, while Man's is flood protection or navigation.

As an engineering treatise, this book of Frisi is chiefly interesting in showing the state of the art at that time and the small amount of accurate Hydraulic Science that had been made sure of 100 years ago. Nevertheless, it is a wonderfully interesting book and raises many questions, and shows that its author had traveled widely and studied diligently. It illustrates better than any other old treatise on Hydraulics, the slow process of organizing knowledge into Science.

It is interesting to read Frisi's criticism of the absurdities into which mathematicians, even the great Sir Isaac Newton, had been led by efforts to develop laws *a priori* from mathematical reasoning, and Frisi's declaration that Hydraulics is a branch of physics rather than of mathematics, and that he especially renounces the hypothetical calculations of his predecessors. Nevertheless, like much that has been written on river science down to the present year, 1922, and is still current, Frisi's own writings are largely flavored with speculative philosophy.

The first clearly written and concise treatise which I have found anywhere is that by the late Mr. Charles S. Storrow, previously mentioned, which was written 83 years ago.

Bennet's translation of D'Aubuisson's "Hydraulics" was another good American book of many years ago, written, I have been told, by a man of exceptionally fine character, mostly at home in the evenings and late at night, while he was trying to cheer up an invalid wife by faithful companionship.

An admirably full bibliography tracing the development of the hydraulic theory of flow in rivers from the earliest times down to 62 years ago, with an appreciation of the contributions to the science by each author, can be found in Chapter III, pages 187 to 228, of Humphreys' and Abbot's "Physics and Hydraulics of the Mississippi." Perhaps the most noteworthy contribution to river training since that time is that of Professor James Thomson on the travel of detritus diagonally across rivers at bends, reported to the Royal Society in 1877 (page 356), or 45 years ago.

It was 65 years ago that the publication of Henri Darcy's researches on flow of water in pipes called attention to the remarkable differences in loss of head, or slope, caused by different degrees of smoothness of the walls of pipes, and developed the parabolic law of distribution of velocities in pipes by means of the Pitot tube; but the remarkable series of experiments on open canals by Darcy and Bazin was not published until 1863, or two years subsequent to the publication of the investigations of Humphreys and Abbot.

These experiments on flow of water in straight pipes and straight open artificial canals, made in France, at Government expense, by Darcy and Bazin, with thoughtfully designed apparatus and special attention to observing the effect of smoothness of conduit wall upon resistance to flow, and measurement of the distribution of linear mean velocities, are a fine example of service of

a well equipped laboratory to Science and the Constructive Arts. The scarcity of similar examples shows that research of this kind must be financed by the Government, or mostly remain undone. Bazin made subsequently some important contributions to data on weir flow, but the data of the epoch-making Darcy and Bazin laboratory researches have not been added to in the sixty years that have followed to anything like the extent that one might expect, nor has the work so admirably begun by Humphreys and Abbot been followed up as the importance of the subject deserves.

Nearly 50 years ago, we had the excellent translation of Weisbach's Hydraulics (first published in German 76 years ago), by our fellow member the late Eckley B. Coxe, M. Am. Soc. C. E., and many admirable college text-books on Hydraulics have been published since, especially notable among which are those of Professor Mansfield Merriman, M. Am. Soc. C. E., Professor Irving P. Church, Affiliate, Am. Soc. C. E., that of David A. Molitor, M. Am. Soc. C. E., giving refinement of formulas, Professor W. C. Unwin, Hon. M. Am. Soc. C. E., the late Professor Bovey, of Montreal and London, Hughes and Safford, and the recent book of Professor William H. Durand dealing with flow in pipes. Revy has described his researches on the great rivers of South America. Cunningham and Gordon, Kennedy and Buckley have written excellent books giving fragmentary observations on the rivers of India, and Thomas and Watt, United States Assistant Engineers of long experience, have published a monumental treatise on the improvement of rivers, dealing mainly with structural designs. I do not find, however, in any of these books the theories, or the data, that we need in training rivers for relief from flood; nor do I find it in the excellent work of Professor Van Ornum, formerly a U. S. Assistant Engineer, or in the works of those authors experienced in the special problems of India, Belasis, Strange, Buckley and Parker, although the two latter present some suggestive data from the Indian works. These latter manuals are intended for the practicing engineer rather than for the college student. Spring's "Training of Rivers on the Guide Bank System", also gives many fruitful suggestions, as does also the development of the "Bell Bund" guide dikes at several Indian bridges.

The reports of the several International Navigation Congresses of the past 20 years give many interesting opinions and some highly useful observations, but as I have read them, the impression has been vivid that they were concerned chiefly, as the title shows, with river training for Navigation, not for Flood Relief. Although the preponderance of authority is for training rivers along the curving lines of Nature, I do not find that the engineers of the great irrigation canals of India which have to take care of some of the worst sediment-carrying waters found anywhere in the world, lay them out on other than the straightest practicable lines. Their problem (like ours in training rivers for flood relief), is the *conveyance of water,* not its navigation, or the fixation of shoals for the convenience of pilots.

In Germany, Professor Hubert Engels has published an admirable treatise dealing with river and harbor structures, of which a new addition is just out, which appears to give a résumé of all recent European writings on river training. In France, Fargue has written much of interest in trying to

formulate laws of river control; but all these treatises have had to deal with scant data, and many of the fundamental scientific laws governing erosion, transportation and deposition of sediments, and the art of river training, are not yet well established. Even Kennedy's laws and rules for silt control in canals and rivers, derived from many observations in India, while heartily approved by many experienced engineers, are questioned or doubted by others.

Three years ago, as previously stated, in preparation for my work in China, I arranged with Hardy Cross, Assoc. M. Am. Soc. C. E., then Assistant Professor of Civil Engineering in Brown University, to make a thorough search for everything in recent contributions to the science and art of river training, which seemed worthy of an abstract, in the principal libraries, beginning with the Corthell Library at Brown University and covering the Libraries of Harvard, the Massachusetts Institute of Technology, Boston Public Library, New York Public Library, Engineering Societies Library, and the Library of Congress, also including the *Minutes of Proceedings* of the Institution of Civil Engineers and the *Transactions* of this Society, and of the several International Congresses for the improvement of navigation and many recent French and German publications. He compiled, with excellent judgment, about 1 000 typewritten pages and photostat copies of abstracts, classified them, and brought them into parallel for my use.

My general impression, born of weariness, after laboriously reviewing his many papers, was that we had collected mainly a mass of conflicting opinions, with a comparatively small amount of new data. This first impression was too severe, for much was found that is interesting and valuable, which I would like sometime to arrange more fully and publish as a volume of classified topical abstracts containing perhaps 500 pages, for the convenience of other students and in the hope that the state of uncertainty thus revealed would stimulate a new departure in research in laboratory and river, that would lead to certainties instead of merely a collection of conflicting opinions.

There is promise of some noteworthy additions to the literature of river training in the near future. Col. C. McD. Townsend, U. S. A. (*Retired*), M. Am. Soc. C. E., for many years Chairman of the Mississippi River Commission has ready for publication a new book, in which all who know of his many years of great interest in river and harbor problems, may hope to find much information of value.

J. A. Ockerson, Past-President, Am. Soc. C. E., reported in the course of his recent address at Dayton, Ohio, on "Flood Problems of the Mississippi",* that work is now in progress on the task assigned to a special committee of its members, "of preparing a full report of the work done under the Mississippi River Commission and the results attained, 'in order to bring together with a view to publication and make available the great mass of valuable data relating to river hydraulics, covering the physical investigations of the varying elements that make up regimen of the Mississippi River, as well as the instrumentalities that have been developed and tried out by the Mississippi River

* *Proceedings*, Am. Soc. C. E., May, 1922, p. 1184.

Commission and its assistants in channel improvement and flood control of the river'."

It is to be hoped this report will be published soon and that it will bring together the valuable views and opinions scattered through the reports issued annually for the past forty years by the Mississippi River Commission, and also all the important data from reports published from year to year as sections of the general report of the Chief of Engineers, U. S. Army, who is charged with all work performed on rivers and harbors under appropriations by Congress.

Although the Science of Hydraulics has made small progress in the past 50 years, the Arts of hydraulic construction have been wonderfully developed in many structures built on a stupendous scale.

The recent Catskill Aqueduct, in a single conduit, has nearly ten times the combined capacity of all the nine aqueducts of Ancient Rome. We now have no occasion to build such magnificent architectural structures as the Pont du Garde, because thanks to the progress in manufacture and the low cost of structural steel, we get far more capacity for less money in a 10-ft. steel siphon. The Los Angeles Aqueduct in boldness of conception far outranks anything of olden time. Moreover, it supplies to the community not only water, but from this water as it flows to the city, it provides electric power and light, which services were not dreamed of even a half century ago. The Hetch Hetchy Aqueduct, now in progress of construction, is on an even more stupendous scale. The Boston Aqueducts, although now outranked in size and length, should not be overlooked, for it was in their construction under the late Joseph P. Davis, M. Am. Soc. C. E., the late Alphonse Fteley, Frederic P. Stearns, and Desmond FitzGerald, all Past-Presidents, Am. Soc. C. E., that a school of scientific water-works construction was established in Boston, the influence of which has spread around the world; as has also the influence of Boston and Massachusetts in safeguarding the purity of domestic water supplies, under the devoted leadership of the late Hiram F. Mills, Hon. M. Am. Soc. C. E., who, shunning all publicity, gave the best that was in him to the service of his fellow men, without fee or salary, during the larger part of his working hours for 30 years.

In power development, also in turbines, the scale of construction has become truly wonderful. About twelve years ago at Keokuk, Iowa, the Mississippi River Power Company had designed a single hydraulic turbine having a power capacity about two-thirds that of all the eighty turbines in Lawrence, Mass., or to all those in Manchester, N. H., and then placed fifteen of these huge units in a row. A few months later, even larger units were put into service at The Cedars, on the St. Lawrence, and now near Niagara, on the Canadian side, there have just been put into service, single units, each of which has a power capacity about equal to the sum total of the developed turbine capacity at Lowell, Lawrence, and Manchester, the three great power cities on the Merrimack, which were three of the greatest water-power centers in the world only a half a century ago. In these great modern water-power developments, the hydraulic turbine yielding more than 90% of the theoretic power in water fall, has been brought as near to perfection as can ever be hoped for.

Meanwhile, water-power development in icebound latitudes has been greatly helped as the outcome of a research in pure science, by Dr. Howard T. Barnes, Professor of Physics in McGill University, who has shown us how to conquer anchor-ice troubles, by raising the temperature of the water less than 0.01° Fahr.

The art of building great dams, both of masonry and of earth, has been developed on the great municipal water supplies for Boston and New York City, and, particularly, for the U. S. Reclamation Service, until now it is proposed to build on the Colorado River, a concrete dam, having its crest 605 ft. above the present low-water surface or higher than the Washington Monument. Its proposed height above bed-rock foundation is 745 ft., or about the same as the topmost pinnacle of the Woolworth Building above Broadway.* In recent years, several masonry dams have been built that are much taller than the Bunker Hill Monument, the granite shaft of which, in Daniel Webster's day, was considered a wonderfully tall masonry structure.

In irrigation works, the hydraulic engineers of the United States, particularly those attached to the U. S. Reclamation Service, under A. P. Davis, Past-President, Am. Soc. C. E., have developed works far beyond even the conception of the Ancients, although they have as yet hardly equalled the acreage brought under the service of water in India during the past century by English engineers.

The canal construction at Panama and the solution of its important hydraulic problems are so well known to all engineers that no especial mention of them is needed here.

Doubtless, I will be criticised for having intimated, in the face of all those stupendous works, that Hydraulic Science has been moving too slowly. In partial answer, it may be said again that it is not the art that has slumbered, but important parts of the science, notably river hydraulics and the means of training rivers to flow peacefully and to carry their load of sediment to the sea, and to dig themselves deeper, if the character of the bed and the general situation permit.

Some explanation for this lack of progress may be found in the fact that some of these American river problems are larger and more difficult than those in other parts of the world, and that it is the American habit to go ahead with the construction without waiting to develop the scientific theory to the utmost nicety. We can build good aqueducts and safe dams notwithstanding uncertainty about the root of h in the Chezy formula or the precise value of the coefficient of discharge for a round crested weir, and can develop power without waiting to untangle all the vagaries of preliminary stream gaugings. Progress in construction is often more profitable than precision, and, for example, at Panama, the Federal Government was wealthy enough to stop the slides by simply digging away everything which it seemed might sometime slide, instead of taking the chances involved in delay while profound studies were being made on the increasing frictional stability of earth by the abstraction of water, or by other means. Nevertheless, in the long run, waste

* See "Problems of Imperial Valley," U. S. Senate Doc. 142, 67th Cong., Govt. Printing Office, 1922, Plate IV, following p. 21.

results from all such lack of knowledge, and this seems particularly true with regard to river training and protection from floods.

Many of these great works just mentioned, have added valuable engineering data. Precise measurements giving the relations of flow, slope, and area, have been made in these great modern aqueducts. Messrs. Fteley and Stearns utilized the Boston Sudbury Aqueduct for their weir experiments. The late Hamilton Smith, Jr., M. Am. Soc. C. E., contributed experiments on pipes in California and on orifices at Holyoke, Mass. Herschel has given the results of experiments on flow in the great steel pipes of the East Jersey Water-Works, etc., and the U. S. Department of Agriculture has given us new and valuable data on the coefficients of flow in irrigation canals and flow in drain tile, which add more patches to that wonderful piece of hydraulic patchwork, the Kutter coefficient for the old Chezy formula. This formula with a coefficient, somewhat ragged after 53 years of wear, still covers fairly well most problems of the construction engineer, but it is high time we had something better.*

Moreover, within these recent years, the art of gauging flowing water has been much improved. Past-President Herschel, in his Venturi meter, transformed an ancient curiosity into a most valuable invention, and recently has partly developed and applied for a patent on a new gauging instrument of remarkable simplicity and promise in his new method of measuring the head and area by means of a perforated pipe on a round crested weir, and B. F. Groat, M. Am. Soc. C. E., has developed the art of Chemi-Hydrometry for which he has received the Norman Medal of the Society.† Meanwhile, the electric generator has given a far more convenient absorption dynamometer for measuring output in water-power turbine tests than the old Prony brake.

A National Hydraulic Laboratory

Early in this address, I mentioned the hydraulic laboratory at the Dresden Engineering School which, although small, has been helping to solve problems of river training, under the skilful management of Professor Hubert Engels, who has devoted his life mainly to studying and teaching Hydraulic Engineering and is the author of one of the best books yet written descriptive of the problems and works of the hydraulic construction engineer.‡

About 20 years ago, Professor Engels established a small laboratory for experimenting on models of rivers and worked out mathematical relations between small and large streams, and demonstrated that the model could give dependable results. In 1913, on the moving of the College to a new site, a new Flussbau Laboratorium was built on a larger scale. This new laboratory was still unduly limited by the space left for him by the architect

* Twenty-nine years ago, hoping to add something to Hydraulic Science, the speaker made elaborate experiments of wide range and great accuracy on loss of head corresponding to a wide range of velocities in all commercial varieties of iron water pipe, tees, and elbows, from ⅛ in. to 8 in. in diameter; also, on new, especially smooth brass pipe, from ½ in. to 4 in. in diameter; also on the loss of head in pipes given the roughest possible interior by lining them with expanded metal lath, and on a great variety of elbows, tees and curves of different radii. He greatly regrets that he has not yet found time to prepare these observations in proper shape for publication, but hopes to finish the reductions and drawings within the coming year. His own shortcomings in failure to publish, make him charitable toward others who might have helped the good cause.

† *Transactions*, Am. Soc. C. E., Vol. LXXX (1916), p. 951.

‡ "Handbuch des Wasserbaues", Leipzic, 1921.

in the basement of the new college building, and hardly a third part as wide or as long as the dimensions that I would suggest for the American National Hydraulic Laboratory. Nevertheless, by the aid of these small models, Professor Engels has worked out various practical problems for rivers and harbors in Germany. A similar laboratory has been built at the Civil Engineering School at Karlsruhe and still another at Berlin. Also, there have been small-scale models built in England and in France for studying river and harbor improvements, and these have been discussed by eminent authorities. After a partial examination of what has been written about them and a review of various discussions of the use of models in the study of river problems, this German type seems best suited for our present needs and promises results of great value *if properly used in parallel with studies on the real river.*

The principal apparatus in the new Dresden Laboratory comprises two canals, or tanks, each about 75 ft. long, the principal canal being about 6.5 ft. wide with an annex, or wing, giving a total of about three times the normal width, within which river bends can be modeled. One tank has a fixed support at one end while the other end rests on jack-screws by which the whole length can be set at various degrees of inclination.* Within this long, tilting tank, a model of the river channel to be experimented on is built up, with all its sinuosities and variations of cross-section. Sometimes the model river bed is built up of earth and sometimes it is made with a base of plaster of Paris, which either can be left bare or can be veneered with earth of the quality under experiment. Sometimes, in studying the deposit of sand-bars, in order to obtain greater visibility, pulverized coal is used to represent the sedimentary deposits, because of its special visibility through the muddy water against the white plaster-of-Paris background.

The same water is circulated over and over again down the model river channel and back through a pipe. By means of a centrifugal pump and by regulating the slope of the tank any desired rate of discharge can be obtained. There are elaborate devices for checking pulsations in the delivered flow, and the experiment can be made with various velocities. After the water has run under a given condition for a time, the model channel can be emptied, and the state of erosion and of deposition of sediment can be observed and photographed.

In Professor Engels' recent publications, the model is shown as arranged for experiments on the Rivers Weser, Rhine, and Danube, and illustrations are given of experiments preliminary to harbor improvements at Düsseldorf, Ymuiden, etc. Also, experiments are described on scour and deposition of sediment caused by various designs of spur-dikes or groynes, some pointing up stream, some down stream, and some squarely across, with photographs showing the deposition of the sand waves developed by the eddies around the ends of these groynes and in the adjacent channel bed. So far as they go the results shown in his publications seem remarkably instructive, considering the small dimensions of his model rivers. He prefers a depth of water not exceeding about 8 in., because with greater depth of sediment-laden water, the motion of the sand grains along the bottom cannot be observed. I am led to believe that

* A recent publication shows the river tank set up on rigid supports.

more convincing results could be had from the larger tank that I would now propose and in which either small or large depths could be used.

I beg that I be not misunderstood as claiming or suggesting that the several problems of river training, and erosion and sand-bar deposition, can be completely solved in such a laboratory. Tests on the model stream, seldom of more than 2 ft. in depth or 10 ft. in width, would be suggestive rather than conclusive, and should be supplemented constantly by reference to the full-size specimen. The mathematical laws of correspondence seem to have been fairly well demonstrated in Professor Engels' laboratory, but by this frequent comparison they would soon become well established. It needs no extended argument to prove that variants in form of dike, jetty, or in slope of river bank, or seashore and bulkhead, and all the varying relations of velocity to erosions, transportation, and deposition of sand and gravel, could be tried out far more quickly and economically in the model, than on the river or shore, and that thereby the number of years through which the threatened communities must wait for relief could be shortened and the deepening of harbors hastened.

My conception of such a laboratory for America, is that it should be National in scope and available for the use of any one of the branches of the service that has problems of the kind that it could help solve. After serving for studies of river flow, coefficients of pipe flow, and crest discharge, it could be quickly refitted to help solve problems of shore protection against wave wash, like those of the New Jersey or the Santa Barbara shores, and when the series of experiments was completed, the apparatus could be maintained at very small expense until the next problem came.

It is not necessary to locate this National hydraulic laboratory on a flowing river or at a water-fall. There are certain advantages of regulation and precision of measurement which can be best secured by circulating the same water over and over again, by pumps of the centrifugal type. One main requirement is a convenient source of electric power, commonly about 50 h. p., seldom more than 100 h. p., for a few hours, intermittently. If the laboratory is further developed with apparatus for new determinations of accurate data for the discharge over large weirs and various forms of dam crests, up to 5 ft. in depth, there might be sometimes a brief call for 1 000 h. p. or more for a brief experiment that could be performed at night or at off-peak hours. The two canals and the main tanks should be housed for winter use and for protection from wind and rain.

In a preliminary and tentative way (but subject to revision after conference with others interested), I am proposing that the tilting tank for the model river be about 250 ft. in length, 20 ft. in width, and about 3 ft. in depth, with a broad wing giving a width of, perhaps, 50 ft. for laying out river bends, and that this tilting tank be fixed at one end at a permanent elevation on a fulcrum or pivot, while it is supported elsewhere by a series of jack-screws about 25 ft. apart, all actuated by worm wheels of varying pitch, proportional to the movement during inclination, so that all can be actuated from a single shaft and motor and the model tank quickly set at any desired gradient, from horizontal to, say, 3 per cent. After a run at one slope, the inclination can be changed in a moment's time by these screws without other-

wise disturbing the model. The same apparatus could be quickly adapted for tests on models of jetties for harbor entrances and for studies of shore protection.

Within this tank, a rough foundation of any convenient material could be shaped to represent a river channel, say, from 5 to 10 ft. wide by 2.5 ft. deep, or smaller, and this base veneered, or covered over, with earthy material from the river in question; or, sedimentary material of the kind carried by this particular river could be stirred into the water while one watched its collection into shoals or sand-bars, and the laws of deposition in eddies behind spur-dikes or retards could be studied. Also, one could study the law of re-distribution of sediments in the bed of a river during floods, by which, in many critical places, material is eroded during a flood from the pool near the concave shore and deposited along the bar, at the point of contraflexure.

One could also develop further information on the respective merits and disadvantages of straightening a channel that has many big bends, which topic has been under dispute since the time of Galileo, and on which I will say more later.

A large amount of much needed information could also be had on the best radius or curvature for the end of spur-dikes placed in series, for maintaining a straight-line channel. There can be no doubt that there is an optimum radius for such curvature and that a dike, with its end curved down stream on a long radius, can be formed so as to lessen the irregularities of the sand waves in the channel bottom and lessen the tendency to undercut the end of the spur-dike or groyne.

Obviously, it is far cheaper to begin the development of the best form of groyne in a small, cheap model than to build a groyne of full-size in the river; moreover, the effect of changes in outline can be far more quickly studied as the experiments progress. One can perhaps cover as wide a range of experiment for finding which is the best form in 6 days on the model as he could cover in 6 months on the river. Nevertheless, studies on the small model and on the large river should go on almost simultaneously, and the distribution of velocities in eddies and the capricious forms of sand waves in river, and in model, must constantly be compared, in order that the tests on the small model may not lead one astray.

The admirable experiments on the transportation of sand and river débris, carried on by Professor Grove Karl Gilbert, of the U. S. Geological Survey, at the University of California, in 1914, could be extended.

The most difficult requirement of all in establishing a National Hydraulic Laboratory, is that of finding a director who shall have a clear head, a broad experience in the field, and a devotion to science like that of the late Professor Gilbert.

Last, but not least, is the matter of swirls and eddies and sundry obscure forms of vortex motion in the water, which some of us who have been observing watercourses for many years, believe are at the bottom of many of the problems of erosion and transportation of sediments. The swirls and eddies of the big river could be studied in parallel with studies in a laboratory of the dimensions proposed. I believe that by glass plates in the walls and powerful

illumination of a thin optical section by means analogous to those used with the ultra-microscope and with the use of bright sand grains and a high-speed motion picture camera, much could be learned about this vortex motion.

The tank in the laboratory of Professor Engels has been used for a variety of other experiments, for example, studies have been made relative to the shaping of jetties at harbor entrances on coast lines where great quantities of sand are swept along by the tidal currents and clog the entrance to the harbor; and studies also have been made of varients in the outline of these harbor jetties, for lessening the deposits, or of disposing of them so as to lessen their obstruction to navigation.

Other trials have been made in Professor Engels' laboratory on the effect of various forms of bulkhead or sea-wall in resisting the action of storm waves, and for obtaining a shape of the vertical cross-section of the embankment or sea-wall that will leave the sand carried by waves and littoral currents in good shape. In order to simulate wave wash on the shore, a volume of water is held back by a gate at the up-stream end of the tank, which gate is lifted suddenly, allowing a symmetrical wave to advance with uniform speed down the channel and impinge on the model of sandy foreshore and bulkhead.

Obviously, this tilting tank could be applied to a great variety of investigations, for example, for an extension to larger sizes of the experiments for determining the laws of flow in drainage pipes, made a few years ago by the U. S. Department of Agriculture. The pipe or conduit to be experimented upon could be blocked up by supports from the bottom of the tilting tank and the water could be run through it at any desired slope, from zero up to 3%, by quickly re-setting the screw supports, which could be done in a moment's time without disturbing the alignment. Such a series of experiments would give much valuable new data on the discharge of partly filled drains and sewers up to cross-sections 5 ft. or more in diameter.

Alongside this tilting-tank canal, I would propose building a parallel canal with concrete walls, say, 240 ft. in length, 15 ft. in width, and 15 to 25 ft. in depth, in which experiments could be made on the flow over models of dams and weirs of various forms, and in which other experiments could be made for determining new methods of precise measurement of velocity in disturbed currents. For certain tests, the current could be given a twist by inclined shear boards attached to the bottom or sides of the tank. In large, filled, circular conduits like turbine penstocks, there is often a surprising amount of twist in the current and sometimes it is present in deep rectangular canals.

There is abundant proof that some supposedly accurate measurements made by ordinary current meters in streams having deeply disturbed currents, have been seriously in error, and the use of such an experimental channel, it is believed, would be of great advantage to the Hydrographic Department of the U. S. Geological Survey, and to many other institutions, in educating its young men in the avoidance of errors in gauging, in addition to other uses in developing new and accurate methods.

In this second proposed experimental channel, provision should be made for weir experiments, with many varieties of shape and roughness of crest, and at greater depths than any heretofore made. A preliminary design for this second

experimental canal has been largely repeated from one prepared by myself ten years ago for a proposed large Hydraulic Laboratory for the Massachusetts Institute of Technology, which was crowded off the campus. This design proposes to circulate quantities of water as great as 600 cu. ft. per sec. by means of centrifugal pumps and to make possible the precise measurement of rates of discharge in a tank, with a limit of error within one-tenth of 1 per cent. It provides for experiments with 5 ft. in depth over a round-crested weir, 15 ft. in length, by utilizing a quick-swinging gate, somewhat after the idea used by Francis in his famous weir experiments, by which in a fraction of a second the weir flow can be diverted from one channel into another and the interval of tank-fill timed by an electric chronograph. This capacity of 600 sec-ft. could be used for experiments at greater depths over the weir by narrowing the sluiceway, also, various much needed data could be obtained on the coefficients of flow through sluices and over drowned weirs. Also, the new method of measuring depth on a round-crested weir, devised by Past-President Herschel and partly tested under a grant from the Engineering Foundation,* could be thoroughly tested.

Many years ago, I became convinced that a standard round-crested weir could be developed that would be superior to the sharp-crested weir and that precision of measurement, particularly in inexperienced hands, can be greatly improved by thus avoiding the disturbances due to eddies and the irregularities in the contracted vein due to swirls and irregular motion in the channel of approach.

Certain preliminary experiments made by the late Mr. Mills, on a "Venturi flume", at Lowell, Mass., indicate that a very instructive series could be run on such a piece of apparatus in this new laboratory, which might develop considerable utility in the constructive arts.

The laws of the so-called "hydraulic jump", which has lately come into prominence as an absorber of energy and thus a safety device for protecting the undermining of dams, could be much better worked out. Through the mathematical investigations of Karl R. Kennison, Assoc. M. Am. Soc. C. E., reported to the Society,† we know that the time-honored formula is wrong and a series of experiments with varying forms of pit and with various forms of deflectors, at the foot of the fall, would aid greatly in showing how best to absorb energy in the friction of eddy currents with maximum structural economy. The absorption of energy at the "jump" comes largely from the friction losses in the violent churning and swirling of the waters in the small open chamber immediately down stream from the jet.

When a set of tests has once been worked out understandingly and carefully, the results are good for all time, within the limits tested, like the weir experiments made by Francis 60 years ago.

This proposed National laboratory would be essentially for experiments on a large scale, leaving to the small-scale college laboratories, about 50 in number, built in recent years, the researches within their capacity.

* *Transactions*, Am. Soc. Mech. Engrs., May, 1920.

† *Transactions*, Am. Soc. C. E., Vol. LXXX (1916), p. 338.

In order to give an example of the capacity of such a river laboratory,* let us consider the biggest problem possible, that of the Mississippi. Problems of German rivers have been studied in laboratory tanks of one-third the linear dimensions here proposed, and let us run an experiment from the point of view of flood relief rather than improvement of navigation.

In the beginning, however, let me say that if this experiment to be next described, was successful in the model, no means yet exist for carrying out such a plan of cut-offs and straightening on so grand a scale as the Mississippi would require. Groynes or retards cannot yet be built capable of holding a river bank 100 ft. high.

If the principle should prove good, there are many smaller rivers on which it could be tried. If the test failed, there might be achieved the valuable result of settling an argument that has been going on since the days of Galileo and of Ancient Rome.

Let there be modeled in the proposed tilting tank a winding stream with a soft or sandy bed, in form analogous to the Lower Mississippi, on a horizontal scale of 1 to 1 000 and a vertical scale of 1 to 100. This distortion of scale probably would not seriously disturb the results. It would be analogous to experimenting on the discharge over a section of dam crest only 3 ft. long, where the entire structure had a crest 30 ft. long. The test could be repeated on natural scale.

Our 200 ft. in length of experimental tank would then represent 200 000 ft., or about 40 miles, along the valley, and its 20 ft. of width would accommodate a bend with an ordinate of nearly 4 miles, while the broad part of the tank would take in a bend of nearly 10 miles ordinate.

Corresponding to the 100-ft. flood depth of the Mississippi, we would have a 1-ft. depth flowing in the tank, and instead of a main river channel, 3 000 or 4 000 ft. in width, the channel in the tank would be 3 or 4 ft. wide.

The slope of the tilting tank would be readily adjusted by the screws to give a velocity, somewhere near to that of the actual river; or such velocity that there would be an analogous slow process of erosion at bends and of deposition of sediment on the nearly opposite convex shoal, with an established regimen showing no important scour or fill along the straighter portions. Although swirls and vortices that exist in the large river, which have much to do with scour and transportation of sediment, might not be found fully represented, there doubtless would be some analogous action in the model stream.

The rise and fall of a flood could be represented by varying the discharge at the pump. Various percentages of sedimentary material could be put into circulation. The formation of bends and action of sand waves could be studied and a great variety of instructive observations made.

After having made various precise quantitative observations on the behavior of the model of the curving, sediment-carrying river in flood, let a section of channel comprising one or two bends be straightened by cutting off the bends and training it to the straightest practicable line, giving it the same average depth as before and holding it from spreading, or wandering horizontally,

* Outline designs for this laboratory are in course of preparation by the speaker, *pro bono.*

by means of dikes and projecting spur-dikes or groynes, which preferably should make the flood channel, say, 10 to 20% narrower than before, in order to encourage the scouring to greater depths.

At the down-stream end of this straightened section let the water be restrained from changing its surface elevation, as by discharge into the Gulf, and at the up-stream end of the section straightened, restrain the bed from being scoured deeper by the swifter current by a "sill", analogous to that built at the head of the Atchafalaya outlet from the Mississippi to prevent its scouring deeper, or analogous to those built at the head of the "Passes".

During this rectifying of channel and enlarging of the cut-off trench some additional head for scour could be had temporarily, if needed, by the water backing up over the sill into the section next up stream, until erosion had lowered the bed.

In addition to increase of velocity and scouring force caused by increased slope, increased depth, of itself, tends to cause increase of velocity with increase of power to erode.

If under the original condition of the curving river, scour and sedimentation were in equilibrium and the regimen thus established over the erodible bottom, then under the new condition this increased current will dig the bed deeper than before, unless the river has a hard resistant bed.

As erosion of the bed progresses the elevation of the water surface along the middle and up-stream part of the straight section will progressively become lower, because of the decreased slope needed to convey the water in the deepened channel. Rapids will be established over the sill placed previously at the head of the section, of increasing height and steepness, until equilibrium is established; and, finally, the current would probably settle down to nearly the same mean velocity all along the straightened river as that originally found in the crooked river; because with a given quality of bed material the control and establishment of a permanent regimen depends on attaining the bottom velocity which is not great enough to dig and is too great to permit deposition. There is commonly some margin between these limits.

The feature of greatest interest and apprehension of trouble is the possibility that with the lessened obstruction from building up the crossing-bar in the curved channel, there would be substituted in the straight channel trouble from sand waves, moving irregularly here, there or anywhere down stream at the rate of only, perhaps, a mile per year. The experiment with the model might give some very useful suggestions. River observations have generally shown that the sand wave did not extend all the way across the channel, like the "crossing"-bar.

The final longitudinal section of the straight river, after regimen is established, probably would differ substantially from that of the natural curving river which works itself into a succession of pools and shoals, deep pools in the bends, with their line of maximum depth following along near the concave shore, which pools are separated by bars of sediment, or coarser gravel, deposited at the place of reversal of curvature—the "cross-over", as the pilots call it—where the channel shifts to near the other bank. In the straight river, the trans-

verse section of the channel will be more nearly of uniform depth and there will be no occasion for gravel bars to accumulate at the cross-over, for there will be no such strongly marked cross-over. Possibly much of this coarser material might find lodgment in the depths of the old pools. With the meander stopped, the supply of coarse material which now builds up the cross-over bars, would be lessened.

In the straight river it is probable that the flood would dig the deposit of sediment more deeply and more uniformly all along, and that the increase of flood height caused by these submerged dams rolled up by the current during a flood, would be substantially reduced.

After one section of model river (or actual river) had been thus trained and its bed lowered, the section next up stream could be undertaken, and the restraining sill between the two sections removed. At each successive stage up stream there would be greater forces available for hastening the excavation, because the amount of fall over the successive sills would be cumulative; and the cumulative change of fall due to the lessened resistance to flow in a straight deep uniform channel and slope possibly would dig the bed enough deeper so that in the upper reaches its floods would no longer reach the top of the banks, and levees no longer be needed.

The reported experience of the past 20 or 30 years with the Atchafalaya channel, below the outlet sill from the Mississippi, indicates that the test would be successful.

The many disastrous effects recorded as resulting from cut-offs of bends in the Mississippi, in past years, seem to have been caused by lack of control. Things simply have run wild under the increased slope of the shortened piece of river. New bends have been eroded, banks undercut, vast areas of fertile land ruined, the products of scour deposited on bars down stream and previously established regimen disturbed, it is said, for more than 50 miles, the disturbed length extending both above and below the cut-off, and the river has not appeared satisfied until the original excess of length has been restored. All this appears to be Nature's method of building deltas and fertile bottom-lands with material eroded from the hills, but after man arrives and needs to cultivate these bottom-lands for a food supply, a change of program may be entirely reasonable. If a cut-off is to be beneficial, it must be under most carefully planned control, with sills, groynes, etc.

As stated previously, however, no practicable type of groyne has yet been developed, that could safely protect and restrain the 100-ft. depth of the Lower Mississippi. Apparently, there now is one that can cope with the Missouri and the Platte, and such laboratory test, therefore, would be applicable to those rivers and many others.

There are a hundred important problems that I have not space here to mention, the solution of which a laboratory on this large scale could hasten. Thoughtfully devised experiments in the laboratory compared with observations on the big river, would develop new lines of analogy, test theories, and surely bring benefits and economies far outweighing the cost of the laboratory, and give basis for deduction from observed facts, instead of mere personal opinions, speculation, and philosophical discussion.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

TECHNICAL PAPERS PRESENTED AT THE ANNUAL CONVENTION, PORTSMOUTH, N. H., JUNE 21ST, 1922

WITH DISCUSSION BY MESSRS. HENRY S. ADAMS, FREDERIC H. FAY, WILDURR WILLING, AND R. S. PATTON.

PROGRESS IN HIGHWAY RESEARCH

By W. K. Hatt,* M. Am. Soc. C. E.

It appears that an early solution of the more complicated problems, and, from the standpoint of National well-being, the graver problems of highway transport, will be reached only in so far as the highway engineer, the highway official, the vehicle designer and manufacturer, and the organizer and operator of highway transport systems, in conference, can come to an understanding of the aims of each, and to a recognition of the public service to which they are called. To this group should also be added, steam and electric railway operators, so that highway transport may find its appropriate function in a co-ordinated structure of National transportation.

The highway engineers and the motor vehicle manufacturers are now seeking a common viewpoint, and are in the way of finding a common purpose from which to reach sound policies in the financing, building, and the use of highways. It is hoped that the contribution of those representing other systems of transportation to a scientific study of these questions may be had.

Co-Ordination of Research.—The Advisory Board on Highway Research, Division of Engineering, National Research Council, is organized to prepare a comprehensive National program for highway research; to assist existing organizations to co-ordinate their activities therein; and to collect and distribute information of completed and current research. This is not a directing, but a service, organization, devoted to the interest of the individual researcher. Services that can be rendered the individual researcher are in soliciting support for his projects, in putting him in touch with his fellow workers through a Census of Research, and in illuminating a particular field with sidelights from allied fields in which a project has its setting. The taxpayer will also benefit through a co-ordinated research activity on problems selected from a comprehensive program with reference to the applicability to present-day problems.

For example, highway researches in the field of economics of operation are connected under Committee No. 1 on the Economic Theory of Highway Improvement, Professor T. R. Agg, M. Am. Soc. C. E., Chairman. In New England, the tractive resistance of automobiles and trucks is being measured on several types of roads at speeds up to 30 miles per hour. The vehicles are tested for internal absorption of energy at the Yale Laboratory by Professor E. H. Lockwood, and the gross tractive resistance determined on the roads by Maj. Mark L. Ireland, Q. M. C., U. S. A., who is stationed at the Massachusetts Institute of Technology. Co-operating in this work are: The Bureau of Public Roads, U. S. Department of Agriculture, the Committee on Economic Theory of Highway Improvement, National Research Council, the Connecticut Highway Commission, the Department of Public Works, Commonwealth of Massachusetts, Harvard University, the Massachusetts Institute of Technology, the Society of Automotive Engineers, the United States Army, Quartermaster Corps, and Yale University.

* Director, Highway Research Committee, Div. of Eng., National Research Council, Washington, D. C.

The investigation includes the effect on tractive resistance of the temperature of the differential of the vehicle, and of various types of tires. The gross tractive resistance is composed of several elements, such as engine, gearing, inelastic resistance of body, tire, windage, road surface, which distinguishes rolling, impact, and displacement resistance. Account must be taken of the absorption and giving out of energy in the rotating parts, in accelerating or retarding speed. The technique of these measurements is not settled. The measuring instrument may be an accelerometer used in coasting tests, or a dynamometer used in towing tests, each of which has its peculiar advantages. The first task is to determine the best instrument to measure the several elements into which the problem is analyzed. The Bureau of Standards has assembled apparatus which automatically records the measurements of about fourteen elements of car performance in road tests.

Professor L. E. Conrad, M. Am. Soc. C. E., at Manhattan, Kans., is conducting a parallel investigation of the resistance of the air to the passage of vehicles.

At the University of Michigan, Professor Lay in a study of economic grades has towed four Packard trucks over gravel and concrete roads, after he had determined their characteristics in the laboratory. The gravel roads varied in condition from wind-swept hard surfaces to a loose gravel surface. The concrete road varied from a smooth finish to a somewhat wavy condition. The gasoline consumption was also reported. The trucks were 5 ton, with 3-ton pay load, and were operated at a standard engine speed of 1 000 rev. per min., the gears being shifted to meet road conditions. Professor Lay finds that for these trucks, the tractive resistance, including rolling resistance, tire resistance, and windage, varied from 40 to 44 lb. per ton on the gravel roads, and from 22 to 26 lb. per ton on the concrete roads, all at a speed of 10 miles per hour. Professor Lay's report is shortly to be published.

At Ames, Iowa, Professor Agg has been investigating the economics of highway location and operation, especially with a view to determining economic grades, and it is expected that his report will be published by January, 1923.

The end in view is a sound economic theory of highway location and improvement. Each of these investigations forms part of a whole. The individual researches profit by intercommunication, and, in the end, the entire results are more likely to be useful in the formation of principles by a co-ordinating service.

In the field of design may be mentioned the experimental road at Pittsburg, Calif., and the Bates test road near Springfield, Ill., investigations of A. T. Goldbeck, Assoc. M. Am. Soc. C. E., of the U. S. Bureau of Roads, and the service test roads at Byberry and Lancaster, Pa., Casper, Wyo., Alexandria County, Virginia, Wilmington, Del., and Milwaukee, Wis. These tests are directed to the same end and will supply co-ordinated data through the Committee on Design; they will place the mechanics of slab design on a scientific basis.

In the field of highway transport, the pioneer transport surveys on the Connecticut roads, started by Commissioner Charles J. Bennett, M. Am. Soc. C. E., have crystallized formerly vague discussions, and have stimulated further

work. The examinations by Dean A. N. Johnson, M. Am. Soc. C. E., of the University of Maryland, by Professor N. W. Dougherty, Assoc. M. Am. Soc. C. E., of the University of Tennessee, by Professor Agg in Iowa, by the Bureau of Public Roads in California, and less complete traffic counts in scores of instances—all these need to be reported and examined for fundamental laws of traffic by a Committee on Traffic Analysis.

A useful and money-saving activity is in the Research Information Service of the Advisory Board, by which a State is informed of the findings from investigations in another State. Cases can be cited in which one State has been saved the delay and cost of an investigation relating to the use of materials, when informed of the completed investigation available from the work of another State. The recent tabulation of the incomplete returns of the Highway Research Census of the Advisory Board indicates not only great activity in this field in the 430 projects, but the possibilities of economy in time and money and the avoidance of unnecessary duplication. Table 1 gives the number of individual research projects in highway engineering and highway transport.

TABLE 1.

	Economics.	Operation.	Design (road).	Construction.	Materials.	Total.
Colleges and universities........	17	3	47	12	127	206
Industrial........................	1	1	3	0	19	24
Municipalities....................	5	1	6	1	18	31
State highway departments.....	13	2	25	8	101	149
State geologists..................	0	0	3	0	17	20
Total........................	36	7	84	21	282	430

It must be said, however, that duplication is not necessarily an evil; indeed, it is useful in fundamental matters, as in the case of the investigation of fatigue of concrete. The parallel investigations at Springfield, Ill., Purdue University, and the University of Maryland, with different methods of attack, will more certainly lead to the truth. However, in these cases, each will profit by communication with the other.

H. S. Mattimore, Assoc. M. Am. Soc. C. E., Engineer of Tests, State Highway Department, Harrisburg, Pa., is Chairman of the Committee of the Advisory Board on the Character and Use of Road Materials; he is also Chairman of the Committee of Tests and Investigations of the American Association of State Highway Officials. The latter Committee is divided into sub-committees, each representing a region of the United States. Mr. Mattimore is furnished by the Advisory Board with an administrative assistant, and this combined attack on problems relating to the materials of construction represents a well-organized committee activity.

These few instances will serve to demonstrate the value of the services of the Advisory Board in combining individual researches.

POLLUTION OF STREAMS BY PULP-MILL WASTES

By George C. Whipple,* M. Am. Soc. C. E.

The manufacture of wood pulp is a hydro-chemical process; consequently, pulp mills are always located on streams or canals. Large volumes of water are required and the waste waters which contain the spent chemicals and the washings of the pulp, pollute the streams. Whether this pollution does damage down stream depends on many factors, namely, the relative volumes of waste and stream flow and the variations in flow; the quality of the river water and the character of the wastes; the opportunity for mixing, the velocity of the current, the existence of riffles, slack water, aqueous vegetation, re-aeration, sedimentation, and the many factors which bring about the natural purification of streams; and, finally, the use which is made of the river water down stream. These factors are common to all forms of stream pollution resulting from hydro-chemical processes, but there are no two places where the conditions are exactly alike. Every polluted stream has its own set of conditions, therefore, generalizations are hazardous. The speaker will only call attention to certain facts regarding pulp-mill wastes and discuss briefly the larger problem of stream pollution by industrial wastes.

It should be noted that the pollution of streams by pulp-mill wastes is only a part of a more general problem—the pollution of streams by trees and tree products—a problem which appears in many forms. Annually, the leaves fall, decay, and the products of their leaching are carried into ponds, brooks, and rivers. Trees die and gradually their wood decomposes. Trees are floated down stream to the mills, and their soakage tends to increase the color of river water, although the effect is not great. Logs are sawed; the saw-dust lies in heaps or washes to the rivers and the pollution takes a different form. All these processes are slow, and the resulting pollutions are regarded as natural. It is only when wood fiber is treated chemically, when vast quantities of logs are brought to one mill, that stream pollution becomes a problem. Pulp-mill pollution is also akin to that of strawboard waste pollution and to beet-sugar pollution, both of which involve the decomposition or chemical treatment of vegetable fiber and the use of water in large volumes.

There are three processes of making wood pulp, which need to be distinguished from each other because of the difference in their waste products. They may be referred to as (*a*) ground pulp; (*b*) soda pulp; and (*c*) sulphite pulp. The object of all these processes is to separate the fibrous from the non-fibrous parts of the wood, the fibrous materials being used for making paper.

Ground pulp is made by cutting logs into short lengths and pressing them against rough grinding wheels kept wet with water. The resulting crude pulp is washed, screened, deposited as a blanket, rolled, and dried. Mechanical pulp thus prepared contains not only cellulose but also lignin and resinous matter. The wash water contains a large quantity of wood fiber and extractive matter, sometimes 10% of the weight of the wood. Chemically, it resembles saw-dust, but is finely shredded instead of granulated.

* Prof. of San. Eng., Harvard Eng. School, Cambridge, Mass.

In the soda process, soft wood, usually poplar, is chipped and digested in hot caustic soda, the resulting pulp being washed, bleached, drained, and worked into the usual blanket form. Soda digestion yields a soft grayish-brown pulp and a black liquor which results from the decomposition of the lignin and resins. A large part of the soda used is recovered by concentrating this black liquor in evaporators, burning off the lignin and other organic materials in rotary furnaces, leaving carbon and sodium carbonate which is leached out and converted back to caustic soda by boiling with caustic lime. As a result, there is wasted a small volume of black-ash sludge which contains a little unleached soda ash, and a large volume of calcium carbonate sludge. A small volume of lime sludge resulting from the bleaching process is also wasted. The liquid wastes consist of wash waters from several parts of the process. They contain wood pulp, caustic soda, and hypochlorites, but are usually not large in volume. In recent years, electrolytic methods of producing caustic soda and calcium hypochlorite from brine have been introduced and savings made which have reduced the waste products. It is said, however, that for every ton of wood-pulp product about 150 lb. of caustic soda are lost.

If all the solid waste products from soda pulp mills were to be discharged into the streams, a serious pollution would occur. Sedimentation basins are usually provided and with them it is possible to retain the bulk of the sludge. The volume of the sludge is very large, however, and in the course of years large areas are required. Unless the sedimentation beds are well operated, foul liquids are likely to be discharged from them, either by drainage or by overflow at times of rain. On the whole, however, the soda process, with its recovery methods, destroys a large part of the lignins and wood extractives by burning, and the pollution of streams by soda pulp mills is a mineral more than an organic pollution.

In the sulphite process, the wood fiber is disintegrated by the use of the sulphites of calcium and magnesium with an excess of free sulphurous acid. Spruce and hemlock are the woods commonly used. The sulphite is manufactured by passing sulphurous acid through a suspension of milk of lime, or by burning sulphur and passing the fumes into an acid tower packed with crushed limestone or dolomite, water being allowed to trickle down as the fumes ascend. The sulphite solution runs out at the bottom of the tower and is pumped to the digesters in which the chipped wood is packed. After digestion for several hours under high pressure, the contents are delivered into a pit from which the waste liquor drains off, leaving the fiber. This waste sulphite liquor has the appearance of a thin molasses, and has a woody, acrid, sulphurous odor. It often contains as much as 10% of solid matter, consisting of wood fiber, lignin, resin, and wood extractives modified by the process. It generally contains sulphurous acid, sometimes as much as 0.5 to 1 per cent. The pulp is screened, washed, and perhaps bleached, and is worked into a blanket ready for paper-making, these processes yielding waste waters which contain fiber and other impurities. It will be observed that in the sulphite process the lignin, resin, and wood extractives are wasted to the stream, whereas, in the soda process, they are mostly burned. For this reason, the pollution of streams

by sulphite pulp mills has proved a more serious matter than that caused by pulp mills using the soda or the mechanical process.

The volume of the liquid waste from a sulphite pulp mill is large and may be as much as 800 to 1 000 gal. per ton of pulp. It is said that for each ton of finished pulp an equal quantity of organic material is discharged into the stream as waste liquor, together with about 400 lb. of sulphur in acid form or organic combination. The action of the bisulphites on the lignin is to produce a mixture of sulphonated substances which give rise to lignin-sulphonic acid or the calcium or magnesium salts of this organic acid.

Earle B. Phelps, Affiliate, Am. Soc. C. E., has given the following average analysis of two samples of sulphite liquor, which may be regarded as typical:

	Parts per million.
Total solids	95 000
Loss on ignition (organic)	82 000
Oxygen consumed	36 000
Ash (mineral)	13 000
Analysis of ash:	
Calcium (Ca)	2 200
Magnesium (Mg)	1 200
Sulphur (S)	2 000
Free SO_2	1 000
Total sulphur (mineral and organic)	10 500

Mr. Melville C. Whipple, who analyzed a sample of the waste sulphite liquor at one of the mills on the Black River, New York, found that it had an iodine absorption equivalent to 224 parts per million of SO_2.

As far as the speaker is informed, no successful method of utilizing or treating sulphite wastes has yet been devised. Its acid condition precludes the use of bacterial methods without prior neutralization and its large quantity of soluble matter makes settling processes of little avail. Evaporation, which is an expensive process, seems to be a necessary preliminary to any method of utilization. The use of detention tanks for equalizing the discharge instead of allowing heavy discharges to occur at intervals, is of some benefit but does not solve the problem. If one considers the damage done and also the value of the substances wasted, it is evident that the prevention of pollution by pulp-mill wastes is worthy of careful study by chemical engineers. Sutermeister states that, in Europe, mills have been obliged to close, because it has been impossible to purify the waste liquors sufficiently to comply with legal requirements. Attempts have been made to use the sulphite liquor as a road binder, a binder for moulding sands, a binder for powdered coal, a fertilizer, a sizing for paper, a food for cattle, a source of dye-stuffs, a material for insulation and artificial leather, or a source of alcohol. The speaker has no practical suggestions to make at this time on the utilization and treatment of wastes but, instead, will discuss briefly the effect of sulphite wastes on streams.

The peculiar character of waste sulphite liquor is its sulphur content, its acidity, and its high organic content. Sulphite mills and often the villages in which they are located, reek with the characteristic odor. Sulphurous acid

escapes into the air in such quantities that the water supply, used for process purposes, when exposed to the air, absorbs it, the natural alkalinity of the water being reduced by measurable amounts. Sulphur in other forms may also be absorbed by the process water, partly from the air, but even more from the pulp during the washing processes. One consequence of this is, that the troughs and channels and even the screens and wash-boxes in a pulp mill become coated with slime which is shown by the microscope to consist of *Beggiotoa, Sphærotilus, Leptomitus,* and other fungi which require sulphur for their growth. The slime problem is often serious in pulp mills and frequent shut-downs for cleaning purposes are required. The slime becomes dislodged from the troughs and settles on the pulp blankets, making dirty spots which affect the sale of the product and sometimes require the pulp to be re-washed. A few years ago, at one of the Canadian pulp mills, the speaker experimented on the control of slime growths by the use of copper sulphate coupled with other chemical treatments, but this experimental work had to be given up on account of the World War. Sufficient was accomplished, however, to warrant the statement that the slime growth can be controlled by proper treatment.

It is a fact which is more than a mere coincidence, that these three filamentous fungi, *Sphærotilus, Beggiotoa,* and *Leptomitus,* found in the water of pulp mills, are also found in sewage polluted waters. Together with *Thiotrix* and, perhaps, *Saprolegnia,* they appear to require sulphur and, either by choice or effect, are found in waters of low dissolved oxygen content. These fungi are often found on sticks and stones in the streams below sulphite mills, appearing as clumps or tufts of fibers, sometimes white like cotton, but more often cream-colored, gray, or salmon pink. When they decay, they blacken and become foul smelling, a condition usually associated with septicity, that is, with lack of oxygen and bacterial decomposition.

Deposits of pulp sometimes occur below sulphite mills where there is slack water. The shores often become covered not only with the fungi mentioned, but with growths of *Oscillaria,* the long bluish-green filaments of which enmesh the pulp. In the sunlight, bubbles of oxygen are generated, which also become enmeshed and float great masses to the surface of the water. Various animal forms take shelter in these oxygenated masses, and other algæ grow on them until they become great centers of microscopic life. If there are other pulp or paper mills down stream, the quality of the water at the lower mills is likely to be seriously impaired for washing purposes. These growths can be kept down by the proper application of copper sulphate.

The practical effect of discharging sulphite wastes into rivers depends on the various factors already mentioned. One effect is to make the stream unsightly by reason of deposits of pulp and fungi and the algæ growths just mentioned, and if a stream once becomes foul in this way, it tends to become a catch-all for many kinds of débris and filth. Uncleanliness is contagious. M. O. Leighton, M. Am. Soc. C. E.,* described the effect of the pollution of Ausable River with sulphite wastes for a distance of twenty miles, and even

* "On the Pollution of Lake Champlain", *Water Supply and Irrigation Paper, No. 121,* U. S. Geological Survey, 1905.

into Lake Champlain. He also described the pollution of Bouquet River with soda pulp wastes. Some thought at one time that it increased the algæ growths in the lake, but this was never definitely proved. Phelps* has also written on the general subject of sulphite pulp wastes and described processes and proposed methods of treatment.

Pulp-waste pollution tends to drive away fish. The fine pulp gets into their gills and the sulphite pollution may kill them by exhausting the dissolved oxygen. The New York Conservation Commission has recently assembled data showing the tolerance of certain fish to industrial wastes and among them are the following: Bass, perch, and trout were killed in about 1 day by sulphite wastes diluted 10 to 1 and when diluted 75 or 100 to 1 trout fry and bass were killed in several days. Dilutions of 100, 200, and 500 to 1 did not kill perch in several days. That death was due to suffocation rather than poisoning was indicated by the fact that a 50 to 1 dilution of the sulphite liquor artificially aerated did not kill perch or bass in 29 days. Bleach sludge diluted 500 to 1 failed to kill perch in 14 days, and aerated bleach sludge diluted 400 to 1 did not kill perch in 5 days. Even if the dilutions are far greater than these figures, sulphite wastes may tend to drive away certain kinds of fish which, like trout and salmon, apparently seek pure waters. There can be no doubt that there are selective differences among fish as to oxygen requirements. It is said that certain of the grosser fish are capable of tolerating pulp-mill wastes, but acquire disagreeable tastes which make them non-edible.

Sulphite wastes may also injure the water of a stream in its use as a boiler water. In at least one instance, such wastes have been known to make the water of a large stream acid, and the damage done by them is often more subtle than that produced by the gross pollution in the vicinity of the mill. The salts of lignin-sulphonic acid, or whatever the compounds may be which result from the action of the acid bisulphite on the lignous and resinous compounds of the wood, have a most persistent odor; even when the sulphite wastes are greatly diluted, it can still be recognized. Formerly, the water supply of Augusta, Me.,† was taken from the Kennebec River, and the imperfectly filtered water often had a noticeable taste and odor resulting from the pulp-mill wastes at Winslow, 17 miles up stream. The water supply of Bangor, Me., is taken from the Penobscot River, and before filtration has the same characteristic taste. At times, the alkalinity is materially reduced and the coagulation of the water rendered difficult. At Watertown, N. Y., the Black River, polluted by sulphite wastes at Deferiet, Herrings, Carthage, and Lyons Falls, has the same taste and odor, which the filter has never been able wholly to remove. The odor is not removed by aeration and the use of chlorine seems at times to intensify it. The municipal authorities of Augusta wisely abandoned the Kennebec River supply and substituted a supply from a pond not far away. At Bangor, in spite of advice to seek another source, the Penobscot supply has been retained and improvements made in the filter plant.

* "The Pollution of Streams by Sulphite Pulp Wastes", *Water Supply and Irrigation Paper, No. 226,* U. S. Geological Survey, 1909.

† "Quality of the Kennebec River Water", *Water Supply and Irrigation Paper, No. 198,* U. S. Geological Survey, 1907.

Unfortunately, it is not the odor alone which causes trouble with down-stream water supplies. The sulpho-lignous organic matter interferes with the coagulation of the water, reducing the efficiency and increasing the cost of filtration. The exact nature of the reactions has not yet been accurately worked out, but some studies have been made at the Watertown filter, which have led to modifications in the process and improvements in the results.

The water of the Black River is deeply stained, its average color being about 80 and its maximum color in different years running up to 135. The quantity of carbonaceous organic matter in the water is greater than that represented by the color. In a discussion* by the speaker before the Society in 1901, on decolorization of water, it was shown that in stained waters the organic matter, as indicated by the "oxygen consumed" test, was 0.125 part per million for each unit of color; but, at Watertown, tests have shown that the oxygen consumed corresponding to a unit of color is often double this quantity. The oxygen consumed is also higher at seasons of low stream flow, when the dilution is less than at other times. Some of the colorless organic matter found at Watertown may be due to sewage pollution, but inasmuch as sulphite waste shows a high figure for oxygen consumed, it is reasonable to suppose that these wastes are an important factor in the Black River. There are visible evidences of this pollution at the Watertown filter, as particles of woody fiber from the waste pulp can be easily detected by the eye; in fact, the superintendent of the filter is in the habit of making a daily record of the approximate quantity of pulp observed in the raw water. Phelps has shown that the "oxygen consumed" in sulphite waste liquor is from 36 000 to 60 000 parts per million; therefore, even after being diluted several thousand times, the water would contain as much organic matter, measured in terms of "oxygen consumed", as would correspond to a color of 100 units. It has been found, as a result of filtration experience, that the quantities of alum required for the coagulation of unstored colored waters free from sewage and industrial wastes, ordinarily bear a fairly definite relation to the color of the water; but in the case of the Black River water, the quantity of alum required is relatively great, largely because of the organic matter from the sulphite wastes. When the water filters were designed by Allen Hazen, M. Am. Soc. C. E., in 1903, it was decided, as a result of experiments made with colored waters, that a period of coagulation of 4 hours would be required, a time considerably longer than previous practice. Experience, however, has proved that even this was not long enough. In 1917, an existing settling basin was converted into a coagulation basin which increased the period of coagulation to about 8 days, and the results of this longer period have proved to be beneficial. Better results have been obtained, although the quantity of alum used has not been lessened. It will be seen, therefore, that, in various ways, sulphite waste pollution increases the cost of water purification.

This is not the whole story, however. Unless coagulation is well accomplished, that is, unless enough alum is used and the time of coagulation is sufficiently long, some of the alum in combination with the organic matter will pass through the filter. Three objectionable results follow, namely, the

* *Transactions*, Am. Soc. C. E., Vol. XLVI (1901), p. 141.

filtered water retains some of the "pulp-mill taste"; the water when heated for ordinary domestic service becomes corrosive, attacks iron, and causes red-water troubles; and the bacterial removal by filtration is not complete. These are all serious matters. Even with what is regarded as good coagulation, the sulphite taste may persist in filtered water.

At one time, as a result of experiments at Watertown, it was thought that basic alum was generally preferable to acid alum for water-filtration purposes. Later studies have made this doubtful. There are, perhaps, times when an acid alum may give better results than a basic alum, waters differ in this respect. With alum made at the filtration plant, as is now often the case, it may be possible to modify its character so as to obtain the best results for any particular water.

Engineers once thought that they had obtained a fairly complete understanding of this problem of coagulation, but experience with mechanical filters, although on the whole successful, has shown that there are many things to learn about coagulation, especially the coagulation of soft, colored waters and waters polluted with such wastes as those from pulp mills. The nature of the colloidal substances, the possible protective effect of colloids on bacteria, the relations between chlorine and organic matter, and the reaction between sulphate of alumina and organic colloids, are some of the subjects which chemists and biologists now have under consideration.

Enough has been said, perhaps, to show that the pollution of streams by pulp-mill wastes is a matter which may cause damage to down-stream riparian owners and affect the health and comfort of many people in communities which take their public water supply from polluted rivers. It also has a bearing on the general problem of conservation of natural resources. Pulp mills not only spoil the rivers, but they despoil the forests. Wood pulp is a useful substance, but there is hardly any raw material that is wasted so lavishly. Without doubt, chemical engineers can solve the pulp-mill pollution problem if capitalists will provide the means, the laws are ample to protect the down-stream riparian owners if they are enforced but, in the speaker's opinion, a better solution of the problem lies in preventive measures, that is, in measures which will protect the forests. Conservation demands that tree trunks suitable for lumber be used for that purpose. It is necessary to find methods of obtaining cellulose such that the newspaper which is in use a day and the paper towel which serves the purpose of a moment are not made at the expense of a tree which has taken twenty years to grow.

The speaker may be wrong, but it appears to him that there is now a greater indifference to stream pollution, a greater laxity in enforcing laws, than was the case before the World War. Probably, this is merely a part of the wide-spread lapse from law and order unfortunately so prevalent at this time. It is a condition which must not be allowed to continue. The pendulum may swing, perhaps, from too much laxity to too much rigidity. The present is a good time, therefore, to consider carefully in a broad spirit of co-operation and in a scientific manner, the best way of dealing with the whole subject of stream pollution. Certain things have been demonstrated by experience. The pollution of a stream may steadily increase without serious offense and with-

out attracting much attention, until suddenly a crisis is reached, the dissolved oxygen disappears from the water and the river is wrecked. It has been learned that it is cheaper and safer to protect a down-stream water supply by filtration than by up-stream treatment of sewage, but that a single line of defense is not enough. It has been learned that many kinds of manufacturing wastes impart tastes and odors to waters, which cannot be readily removed by water filtration and that chlorination sometimes accentuates them, and that these tastes and odors may be produced even when the polluting substances are very dilute. It has been learned that river-pollution problems are not all related to the public health. It has been learned that because rivers flow between States and from one State into another, the control of pollution by independent State action is not adequate to meet the situation, and yet the police power resides in the sovereign States. It is evident that some new mode of procedure is necessary to deal with the situation; yet it is doubtful whether any better legal remedies will ever be devised than the application of the principles of common law and the exercise of police power by the separate States. The speaker does not favor delegation of the police power to the Federal Government in this matter, and at present the powers of the Federal Government are limited to navigable streams.

A uniform policy throughout the country is much needed. To secure this, a thorough scientific, economic, and legal study of the whole subject of stream pollution should be made on a National scale by a joint committee representing the National bodies interested in the different phases of the subject, under the sponsorship of one of the Federal Departments with Congressional authority and an adequate appropriation. This committee, after several years of investigation, should formulate a policy, suggest model laws, and recommend their adoption by the several States. It may be possible to organize river districts independent of State boundaries, with commissioners whose duties would be to secure co-operative efforts to keep the rivers clean and to utilize the waters of the streams to the best advantage of all the people living within the districts, leaving all legal actions where they now are and where, in the interest of good government, they should remain. The whole subject at present is in a chaotic state. Some State Departments of Health attempt to exercise almost despotic powers over the streams; in other States, their action is chiefly advisory; and, in some States, there are pollution commissions independent of the health authorities. Although there has been a recent laxity in law enforcement, it is hoped that the next move will not be toward a too arbitrary enforcement of ill-considered laws, but that means will be found to accomplish by co-operative effort what is so difficult to accomplish by law. It would appear that the Society is one of the organizations which should take the lead in this important matter of conservation.

WASTES FROM PULP AND PAPER MILLS CHEMICALLY CONSIDERED

By H. W. Clark,* Esq.

There are two main points of view concerning pulp and paper-mill wastes: (1) That of the owner of the mill who wishes to discharge wastes of no value into the streams on which the mill is located; and (2) that of the sanitary engineer who wishes to keep the stream in as unpolluted a condition as can be reasonably required.

Where industrial streams are not used for water supply, about all that is necessary in the treatment of industrial wastes is purification sufficient to prevent the stream from becoming a nuisance to the community, on account of its appearance, deposits on its banks, and odors. If possible, it should be kept clean enough to be a source of enjoyment to this community. Where streams are polluted by pulp and paper-mill wastes too large in volume to be properly diluted and cared for by the volume of water into which they go, and this stream must be used farther down on its course as a water supply after filtration, efficient treatment of these wastes is not only desirable, but necessary.

The speaker began to investigate the pollution of streams by wastes from pulp and paper mills about twenty-seven years ago and has been obliged to consider the subject of paper-mill wastes both from the viewpoint of the sanitary engineer and the manufacturer who hesitates to expend large sums to satisfy extravagant demands for the prevention of stream pollution.

Many kinds of wastes result from the making of paper and a more or less complete classification of them is as follows: (1) The wastes from pulp mills where wood, either poplar or spruce, is treated; (2) the wastes from digesters in mills making paper from material other than wood pulp, that is, from old rope, carpets, bagging, old paper, etc., and as this stock is treated in digesters, the wastes resemble those from wood-pulp mills; (3) the waste liquor, very polluted, produced by washing and beating such stock before it is treated in digesters and made into paper; (4) the waste from mills in which rags only are the stock treated with milk of lime in rotary boilers; and (5) the wastes from making pulp of all kinds into paper.

At present, the wood-pulp mills treat either poplar, spruce, or hemlock, the poplar being treated by the soda process and the spruce and hemlock by the sulphite process. Owing to the decrease in the supply of poplar, the sulphite process is perhaps gaining materially over the soda process. Two classes of waste liquor are produced, one from each process. At many mills, the digester liquor from the soda process is evaporated and the used chemicals recovered, thus preventing the discharge of much waste liquor. The liquors from the sulphite process generally go to waste, that is, are discharged into the stream on which the mill is located. The following statements concerning two typical pulp mills in Massachusetts, one using the soda process and the other the sulphite process, can be made.

* Chf. Chemist, Massachusetts Dept. of Public Health, Boston, Mass.

In the pulp mill using the soda process, 2 500 lb. of soda ash are used for each charge in the digester, this soda being causticized 90% before use and the residual calcium carbonate resulting from this process used in sizing. Of the 2 500 lb. of soda used in each charge, about 500 lb. is new, whereas the remainder has been recovered from the black ash of previous digestions, the digester liquor having been evaporated and calcined. At this mill, about 5 000 000 gal. of this digester liquor is produced annually, of which only about 10% is wasted, being lost during the washing of pulp after digestion, the remainder being evaporated for this recovery of chemicals. The analysis of this waste liquor from the soda process is as follows:

	Parts per million.
Total solids (no suspended solids present)	132 000
Loss on ignition	72 100
Fixed solids	59 900
Alkalinity (methyl orange)	39 000
Free ammonia	34.00
Albuminoid ammonia	72.00
Oxygen consumed	27 600

Volume for volume, this liquor is perhaps one hundred times as deleterious to a stream as domestic sewage. It contains a large quantity of organic matter and its oxygen demand while comparatively slow, is enormous, perhaps twenty times that of average domestic sewage. In 24 hours, 1 gal. of this waste will absorb 10.78 grammes, or 7 544 cu. cm. of oxygen. It is so alkaline—practically 4%—that it destroys bacterial life in the water into which it flows, and it is deadly to fish. Fortunately, the volume wasted is small and will probably decrease as the recovery of chemicals increases in favor.

A different story must be told of the liquor from the sulphite process. At the plant under discussion none of the digester liquor is recovered, about 17 000 000 gal. being discharged annually into the stream on which the mill is located.

The speaker believes that in a few cases this liquor is concentrated by evaporation or is treated so that it becomes useful for certain purposes. It contains 4 000 parts per million of organic acid, which should make its recovery of value. During the World War, experiments were made looking to the recovery or manufacture of alcohol from it. An analysis of this waste from the sulphite process is as follows:

	Parts per million.
Total solids (no suspended solids present)	74 100
Loss on ignition	66 300
Fixed solids	7 800
Alkalinity (methyl orange)	—800
" (phenolphthalein)	—5 000
Sulphur dioxide (as sulphurous acid or sulphites)	400
Free ammonia	146
Albuminoid ammonia	62
Oxygen consumed	34 600

This waste is acid and contains practically as much organic matter as the soda-process waste. Its oxygen demand on the stream it enters, appears to be somewhat less, and it is slightly less deadly to bacteria and to fish. In 24 hours, 1 gal. of this waste will absorb 8.71 grammes or 6 088 cu. cm. of oxygen. There is no reason why the treatment of this liquor should not be demanded where sanitary conditions require it, as it probably can be evaporated and products recovered which would pay at least for the cost of treatment. Neither of these liquors can be satisfactorily treated by any known method of purification other than evaporation and recovery of bodies of value. They are exceedingly inimical to bacterial life, and if mixed with sewage, or other liquors, and passed to filters, they destroy the value of such filters.

As stated previously, wastes from certain paper mills consist of the liquors from washing old stock worked up, from treating this stock in digesters, and from the paper machines. In such mills, soda ash, lime, bleaching powder, white clay, etc., are used and a large part of these chemicals are wasted. There is generally no saving of soda ash or other chemicals in mills using mixed stock. The true wastes, however, are largely carbonaceous, and in order to purify or clarify them satisfactorily, dependence must be had on straining, sedimentation with or without the use of preciptants, and filtration through filters of sand, cinders, or like material. In the treatment of domestic sewage, nitrification by bacterial action is depended on where a high degree of purification is required, but the small amount of nitrogen in paper-mill waste renders this process of little value.

Investigations at the Lawrence Experiment Station showed that when a liquor to be treated contained an x amount of nitrogen and from $10\,x$ to $12\,x$ of carbon, nitrification would still take place in a filter, but that it was practically killed when the amount of carbon was $13\,x$ or $14\,x$, or greater. In this investigation, studies of the behavior of paper-mill wastes under certain conditions of filtration were made, together with complete analyses of such wastes, to determine the relative amount of nitrogen and carbon present in them. Some bacterial action, however, does take place in filters receiving carbonaceous wastes, this purification without nitrification being due to certain bacteria which are active under conditions that prevent nitrification, but which cause chemical actions that break down organic matter and result in the setting free of carbon dioxide and nitrogen.

Much of the organic pollution in paper-mill wastes is in suspension, and a considerable part is quite readily removed by passing the liquors through fine wire screens. In some mills, a large part of the pulp formerly wasted from the paper machine is saved in this way, and a large part of the dirt in various wash waters can also be screened out. Besides screening, sedimentation is depended on at many mills to save pulp, and at such places aluminum sulphate is also generally used to aid sedimentation. The paper fiber saved in this way much more than repays the cost of construction and operation of sedimentation tanks and the aluminum sulphate used. The aluminum hydrate produced and unavoidably mixed with the pulp used, is of value, generally speaking, in the weighting of paper and often as much as 4 or 5 grains per gallon of sulphate is

used in this saving of fiber. The quantity of oxygen absorbed in 24 hours by wastes from a mill representing the class using mixed stock is shown by Table 2.

TABLE 2.

Sample.	Dissolved Oxygen Absorbed by 1 Gal. in 24 Hours.	
	Grammes.	Cubic centimeters.
Rotary boiler wastes	2.2720	1 589.0
Washer wastes	0.4920	344.2
Settled washer wastes	0.2272	158.9
Machine wastes	0.1136	79.5
Settled machine wastes	0.0304	21.2

When the speaker first began to study paper mills and their wastes, hardly a "save-all" was in use and none of the elaborate sedimentation and precipitation tanks that are in common use to-day. Besides the saving of machine wastes by the tanks, etc., the pollution of streams is prevented by screens and sedimentation tanks through which are passed the waste liquors from the washing of old stock. About 30% of the matters in suspension is generally eliminated in this way by 4 hours of sedimentation and from 90% to practically all the matter in suspension can be removed if 75 to 100 grains of aluminum sulphate per gallon, are used. This means from 10 000 to 14 000 lb. per 1 000 000 gal. and is a large amount of precipitant, but it is being used in some mills where it is necessary to prevent the pollution of streams. Where several million gallons of waste are produced by one mill, the removal by sedimentation alone of even 30% of the matter in suspension means much reduction of river pollution. More than this, sedimentation and filtration can be depended on to treat the mixed wastes for further purification. The rates of filter operation vary with the quality of the liquor being treated, but rates of from 200 000 to 500 000 gal. per acre per day are used with good results. By a combination of all these methods—screening, sedimentation, and filtration—it is often possible to remove 70% or more of the primary polluting matters of paper-mill wastes. Apparently, however, the only wastes recovered with profit as yet are those from the soda-pulp process and the wastes from the paper machine. Much research work is being done, and it is probable that valuable discoveries will be made.

THE TREATMENT AND DISPOSAL OF STRAWBOARD WASTES

By H. B. Hommon,* Esq.

This paper gives a complete account of the studies made at the American Strawboard Mill, Noblesville, Ind., for developing methods to treat wastes resulting from the manufacture of paper from straw.†

Process of Making Paper from Straw.—Strawboard mills are generally located in wheat-growing districts. The straw is purchased from the farmers, baled, and shipped to the mills where it is stacked in large piles. The first step in the process of making paper is to cook the straw in large ellipsoidal rotating steel boilers with steam and lime, about 1 ton of the mixture to 6 tons of straw, until the woody fiber is softened, and the whole mass has been reduced to a dark yellow pulpy consistency. The yield of pulp at this point is about 75 to 80% of the weight of the original stock. The pulp is removed from the boilers, allowed to drain, and then placed in beaters and washers, where it is broken up and the lime, fine particles of straw, and other foreign material washed out.

From the washing machines, the pulp is carried by water to the paper machines, where it is taken up on felts and delivered to a train of hot rolls that turn out the finished product.

Volume of Wastes Produced.—Of the many sources of wastes from a strawboard mill, only two produce large quantities, namely, the washing and the paper machines. These two wastes come from separate parts of the mill and differ widely in composition, but they are approximately the same in quantity. While the tests were being conducted at Noblesville, a survey was made of seven other strawboard mills, in order to determine how far the analyses and flow data obtained at the experiment station were representative of the entire strawboard industry.

As already stated, the pulp from the cookers or rotaries is washed to remove the lime, fine particles of strawboard, and other foreign material. The quantity of water used for washing the pulp varied considerably at the different mills where measurements were made, but the average was 18 200 gal. per ton of strawboard made. This figure checks closely the average for a long period at the mill where the experiments were conducted.

The waste from the paper machines consists of the water used to carry the pulp to the train of rolls. The measurements obtained at the various mills visited, showed variations, but the average, 19 900 gal. per ton of finished product, was almost identical with that obtained from the flow data at the experiment station. Therefore, about 38 500 gal. of waste was produced for each ton of strawboard made.

Composition of Wastes.—The waste from the beaters or washing machines was by far the most concentrated of the two, as it contained the chaff, minute particles of straw, and small particles of other organic matter washed from

* San. Engr., U. S. Public Health Service, San Francisco, Calif.

† Data taken from *Bulletin No. 97*, U. S. Public Health Service.

the pulp after digestion in the boilers. This waste also contained the lime washed from the digested pulp.

When the survey was made of the seven strawboard mills to determine the volume of wastes produced, a series of composite samples were collected from the wastes from the washing and paper machines and shipped to the central laboratory in Cincinnati, Ohio, for analysis. The results of the analyses of the washing machine wastes showed that the total suspended matter varied from 3 000 to almost 9 000 parts per million; the suspended matter in the supernatant after 24 hours of settling, varied from 450 to 2 400 parts per million; the organic nitrogen, from 47 to 105 parts per million; the alkalinity as carbonates, computed as $CaCo_3$, amounted to 1 870 parts per million; the oxygen consumed varied from 1 480 to 3 400 parts per million; and the oxygen demand, 10 days at 20° cent., from 1 850 to 3 600 parts per million.

The waste from the paper machines contained only the small quantity of fiber and other finely divided material that passed through the screens, together with the lime left from the washing process. The analyses from the mill where the tests were made and from the other seven mills covered in the survey, varied within the following limits: Total suspended matter, range 440 to 991 parts per million; suspended matter in supernatant liquor after 24 hours' settling, 60 to 460 parts per million; total organic nitrogen, 10 to 43 parts per million; carbonate alkalinity found in only three wastes of the eight reported; oxygen consumed, 191 to 970 parts per million; and oxygen demand, 10 days at 20° cent., 111 to 890 parts per million.

The analyses of the composites of the two wastes at the experiment station for the period of the tests checked the averages of the results from the mixed wastes at the other seven mills, within reasonable limits.

On the basis of the figures given for the average total volume of waste per ton of strawboard manufactured, and on the rated capacity of the mills in the United States in 1918*, there were approximately 20 000 000 000 gal. of waste discharged from the various plants during the year. Computed on the basis of the average suspended matter in the mixed wastes from all the plants visited, there were approximately 161 000 tons of dry suspended solids discharged from the strawboard mills in 1918. Much of the material was short fibers of straw, which the type of machinery in use at that time could not save.

Treatment of Wastes.—The experiment station was operated at the American Strawboard Mill from January 1st, 1915 to June 30th, 1916. The test units consisted of two settling tanks each 8 ft. in diameter by 10 ft. deep; one chemical reaction tank, 6 ft. in diameter and 10 ft. deep; one chemical settling tank, 8 ft. in diameter and 10 ft. deep; one chemical solution tank, 5 ft. in diameter and 6 ft. deep; one mechanical filter, 8 ft. in diameter and 6 ft. deep; two filters, 8 ft. in diameter and 10 ft. deep; one filter, 6 ft. in diameter and 10 ft. deep; and one filter, 8 ft. in diameter and 6 ft. deep.

From January 1st to July 1st, 1915, the plant was operated on the principle of mechanical filtration. Alum alone and lime and iron were used as coagulants. The results obtained were unsatisfactory, due mainly to the large

* "Lockwood's Directory of the Paper and Stationery Trades", 1918.

quantities of chemicals required for efficient coagulation, the very low rates of filtration through the mechanical filter, and the high percentage of water required to wash the filter. As this method of treating the waste was impractical, further description of the plant, or discussion of the analyses of the various effluents, will be omitted for this period of operation.

During July, 1915, the plant was remodeled and operated until the close of the tests on the principle of biological treatment of the wastes. The two settling tanks were retained and operated as during the first period, but all the other tanks were turned into filters. The filters were constructed as follows: One, 6 ft. in diameter, having 5 ft. of limestone screenings; one, 8 ft. in diameter, having 5½ ft. of 1½-in. limestone; one, 8 ft. in diameter, with 5 ft. of unscreened cinders; one, 8 ft. in diameter, with 5 ft. of screened cinders; and one small screened cinder filter, 4½ ft. deep.

Results Obtained at the Experiment Station During Period 2.—The test units were operated for about one year in this period, and the results showed that strawboard wastes of the character produced at the American Strawboard Mill in making paper from straw could be treated so that the final effluent could be discharged into a stream of water having a dilution factor of at least 5 or 6, without creating a nuisance in the stream or killing fish.

The weighted average for the suspended matter in the mixed raw waste for Periods 1 and 2 was 1 760 parts per million. During Period 2, the averages for total nitrogen and oxygen consumed were 29 and 910 parts per million, respectively. The carbonates and bi-carbonates were 141 and 598 parts per million, respectively. The oxygen demand at room temperature for 24 hours was 40 parts per million.

The raw waste was settled in tanks for a period of about 2 hours, and the average suspended matter in the effluent was 680 parts per million, which is a reduction of 53 per cent. This was computed on the suspended matter in the raw waste during Period 2. The advantage of longer storage periods over 2 hours was practically negligible. The total nitrogen averaged about the same for the tank effluent as for the raw waste. The carbonate alkalinity was reduced by the tanks from 119 parts per million in raw waste to 63, and the bi-carbonate was increased from 533 to 558 parts per million. The average for the oxygen consumed was reduced from 720 to 575 parts per million.

The effluent from the tanks was treated on filters of the different sizes, kinds, and depths of filtering material already described. Those of coarse and fine limestone and of unscreened cinders did not give satisfactory results and discussions of them will be omitted. Two filters of screened cinders, one 8 ft. in diameter and 5 ft. deep, and the other, 4.5 sq. ft. in area and 4.5 ft. deep, produced satisfactory effluents. The smaller of the two filters was in operation 11 months and the larger, 9 months.

The average analyses of the effluent of the large screened cinder filter compared with the average results from the influent are given in the Table 3.

The suspended matter in the effluent of the large, screened, cinder filter had none of the characteristics of that in the effluent of the settling tanks or in the raw waste. It was more like humus. The final effluent had a slight

yellow cast and there was no odor. The nitrification was low, but samples diluted 1:3 with tap-water were stable by the methylene blue test for 90 hours.

TABLE 3.

	Influent, in parts per million.	Effluent, in parts per million.
Suspended matter	918	115
Carbonates as $CaCO_3$	121	29
Bi-carbonates as $CaCO_3$	528	417
Oxygen consumed	742	133
Oxygen demand (24 hours, room temperature)	54	9.5
Nitrogen, total organic	29	9.1
Nitrogen as nitrites	....	0.035
Nitrogen as nitrates	....	1.3
Hours to reduce methylene blue at room temperature, dilutions, 1:10 and 1:3, respectively	40	90

In considering the results of the analyses of this filter effluent, it should be borne in mind that the organic matter of the waste was mostly cellulose that had been worked over in the bed, and that in its final condition it was not different from the material washed from woods or lands covered with decayed vegetation. When the filter was examined at the close of the tests, the top layer of material had a deposit resembling the original pulp; but below the upper half of the bed, the color of the deposit was dark and it was alive with earth worms and other small organisms. The odor was much the same as that noted when digging into soil rich with decayed organic matter.

The filter contained considerable organic matter, but it did not have the same effect on the effluent that an equal amount would have on a sewage filter, probably for the reason that the clogging material was of uniform composition and the life in the filter was capable of reducing it before anærobic action could be established. After the filter was examined, it was flushed with water and the filtering material thrown out of the beds. The first water from the flushing carried out large quantities of black flocculent matter and masses of earth worms and other organisms, and, later, the accumulation from the top layers came through. While digging out the cinders, it was observed that the voids were fairly clear and that the material remaining after flushing was gathered around the filter media. It is believed that cinders screened over a $\frac{1}{4}$-in. screen, or thoroughly washed with water, can be used for many years to treat settled strawboard wastes, but it may be necessary to flush the beds about once a year to remove the clogging material from the lower half of the bed. There probably would be no objections to using settled waste for flushing, but if water is available it should be used, as it would freshen the filter and not add the same burden of organic matter to the receiving body of water that would result from using the settled waste.

Settling Period and Rates on Filters.—The settling periods in the tanks at the experiment station varied from 2 to 8 hours. The suspended-matter results for the various periods showed conclusively that 2 hours of settling was sufficient to remove practically all the settleable matter that could be removed by tank treatment in an economical period of time. The screened

cinder filters were operated for several months at a net rate of 400 000 gal. per acre per day, and the results obtained were satisfactory. This rate has been set as the maximum for settled strawboard wastes, and it is believed that it can be maintained for many years, provided the filters are flushed with water or tank effluent whenever they become clogged so that the influent does not flow readily through the beds.

Treatment of the Wastes by the Activated Sludge Process.—Laboratory tests were made to determine whether this process would be applicable to this class of wastes. Air was blown through sewage in large-bore, glass tubing until a satisfactory floc had been obtained and then waste was added gradually to replace the sewage. The results obtained after prolonged aeration were not satisfactory as the supernatant liquor after settling 30 min. invariably contained about 105 parts per million of suspended matter and the color was only slightly less than that of the raw waste. The analyses did not show as high degree of purification as that obtained by the tanks and filters.

Accumulation, Composition, and Disposal of Sludge.—Careful measurements and analyses were made of the sludge deposited in the tanks. The measurements showed that about 2.75 tons of dry solids were deposited per 1 000 000 gal. of waste treated and this, computed to 87% wet sludge, gives 24 cu. yd., or 0.9 cu. yd. per ton of product.

The analyses of the sludge in different stages of decomposition, and of horse manure are given in Table 4.

TABLE 4.—ANALYSES OF STRAWBOARD WASTE SLUDGE AND HORSE MANURE.

Source.	Percentage (Dry Basis 100° Cent.)			
	Total nitrogen.	Calcium as $CaCO_3$.	Total phosphorus as P_2O_5.	Total potassium as K_2O.
Fresh sludge from settling tank......	0.69	21	0.38	0.54
Digested sludge from settling tank....	1.0	23	0.48	0.42
Sludge from old settling pond..........	0.66	37	0.29	0.25
Horse manure* (including litter.)......	1.7	....	0.26	1.50

* Data from *Bulletin No. 246*, Ohio Agricultural Station, p. 726.

The disposal of the sludge presents a rather difficult and expensive problem. On the basis of the data obtained in the tests, there would be produced at the American Strawboard Mill about 3 tons of dry solids per 24 hours, or about 26 cu. yd. of wet sludge. The only practical method developed for disposing of the sludge was to dry it on shallow beds of cinders and apply it to land under cultivation for grain grown in sections where wheat is raised. Field tests were made, using the dried sludge as a fertilizer, and satisfactory increases in yield were found for corn when 8 tons per acre were used. As nearly as could be determined, the sludge had about the same value as a fertilizer as ordinary yard manure. In small box tests, the dried sludge invariably increased the yield of wheat, oats, and vegetables.

Effect of Filtered Waste on Fish Life.—A small box, 3½ ft. long by 2½ ft. wide by 1 ft. deep, was placed under the outlet from the large, screened filter bed. The effluent discharged into this box was diluted with 1 part of fresh water, and into this mixture 20 minnows were placed. In this dilution, the fish lived from May 8th to July 1st, when the experiment station was dismantled.

Treatment Plant Recommended.—On the basis of the data obtained in the tests, it was recommended in the report that settling and sludge storage capacity of about 975 cu. ft. per ton of daily output from the strawboard mill be provided in ordinary plain settling tanks. For drying the sludge, it was recommended that 875 sq. ft. of filter area be provided for every ton of strawboard made and that the beds be made of unscreened cinders about 10 in. deep.

The filters used in the tests that were most satisfactory, were made of screened cinders 5 ft. deep, and the highest rate of treatment that gave satisfactory results was 400 000 gal. per acre per day. On the basis of these data, it was recommended that 4 171 sq. ft. of filter area be provided for each ton of product made, or 772 cu. yd. of cinders per ton.

Conclusion.—At the time the experiment station was placed in operation, no practical method was known for treating wastes produced from the manufacture of paper from straw. Where this type of waste had caused serious nuisance in the receiving bodies of water, dikes had been constructed, sometimes enclosing as many as 50 acres of land, and the ponds thus made were used as a means of storing wastes. Evaporation and seepage into the ground were taking care of the waste.

The testing station was planned and operated to modify the character of the waste so that the organic matter in the final effluent, whether in suspension or solution, would not draw heavily on the oxygen supply of the receiving body of water or kill fish, and would not form offensive sludge deposits.

It was believed that this was as far as the first studies should go, leaving the subject open for further investigation, with particular reference to the effect of the treated waste on water filtration plants purifying water from bodies of water containing the waste. This phase of the problem can be studied only after large treatment plants have been placed in operation.

The results obtained in the tests showed that strawboard waste can be treated at a reasonable cost, so that a body of water affording a dilution factor of at least 5 or 6 can receive the final effluent without danger of causing a nuisance or killing fish. In low dilutions, there will be some increase in color from the treated waste and an increase in the alkalinity, but no harmful bacteria will be added, and it is believed that domestic sewage from sprinkling filters will have more effect on a stream of water than an equal volume of the treated waste.

A complete description of the experiment station, together with a large amount of analytical data and the final recommendations in detail are given in the report of the tests.

RELATION OF WATER POWER TO THE PULP AND PAPER INDUSTRY IN CANADA

By J. B. Challies,* M. Am. Soc. C. E., and I. J. Johnston†

The purpose of this paper is to illustrate the important assistance contributed by various branches of engineering to the development of pulp and paper manufacture in solving the unusually large power requirements of this industry. Motive power for the production of pulp and paper is vital, being almost as important as the raw material. The importance of cheap power may be judged from the fact that it requires practically 100 h. p. to make 1 ton of paper per day. In the various processes followed, the average figures of a large Canadian mill show that mechanical pulp requires 73 h. p. per ton of daily output, of which 67 h. p. is for grinding alone; sulphite pulp requires 8.7 h. p. per ton of daily output, and in other large mills as high as from 20 to 30 h. p., whereas the production of newsprint from pulp consumes 12 h. p. for the same unit output. The continuous operation of mills in this industry, usually 24 hours per day, permits an advantageous use of power, and direct water power or hydro-electric energy further allows a cheap unit cost for the amount consumed.

Importance of Pulp and Paper Industry in Canada.—The development of this industry in Canada has been rapid and the cheap power required brings it in close touch with the hydraulic resources. These facts recently led to a special survey of conditions by the Dominion Water Power Branch of the Department of the Interior, Ottawa, and the various data here presented are largely based on the information thus gathered. The remarkable expansion during the last generation may be judged from pulp and paper export trade of Canada, which is said to have amounted to only $120 in 1890 as compared with the present figure of more than $100 000 000. According to the figures of the Bureau of Statistics, for 1920, the pulp and paper industry in Canada represented a total capital investment of $347 553 333, found employment for 31 298 persons whose yearly wages and salaries amounted to $45 253 893, and the value of the products totaled $214 421 546. The fact that this industry requires large quantities of cheap power practically restricts it to hydraulic energy and the position acquired by Canada in this field rests on adequate and abundant water powers well distributed among extensive forest resources. The importance of cheap power in the manufacture of pulp and paper may further be gauged by a comparison with other Canadian industries, the power requirements of which are also large. Census figures for 1920 show that for every 100 h. p. installed in the pulp and paper industry, lumbering had only 60 h. p.; flour mills 20 h. p.; and cotton mills, 10 h. p.

Total Power Installation.—In this paper and in Tables 5 and 6, the general term "pulp and paper mills" refers to all mills, whether they produce only pulp or paper or both these products.

Fig. 1 is a map of Canada showing the location of pulp and paper mills operated by water power or hydro-electric energy.

* Director, Dominion Water Power Branch, Dept. of the Interior, Ottawa, Ont., Canada.
† Ottawa, Ont., Canada.

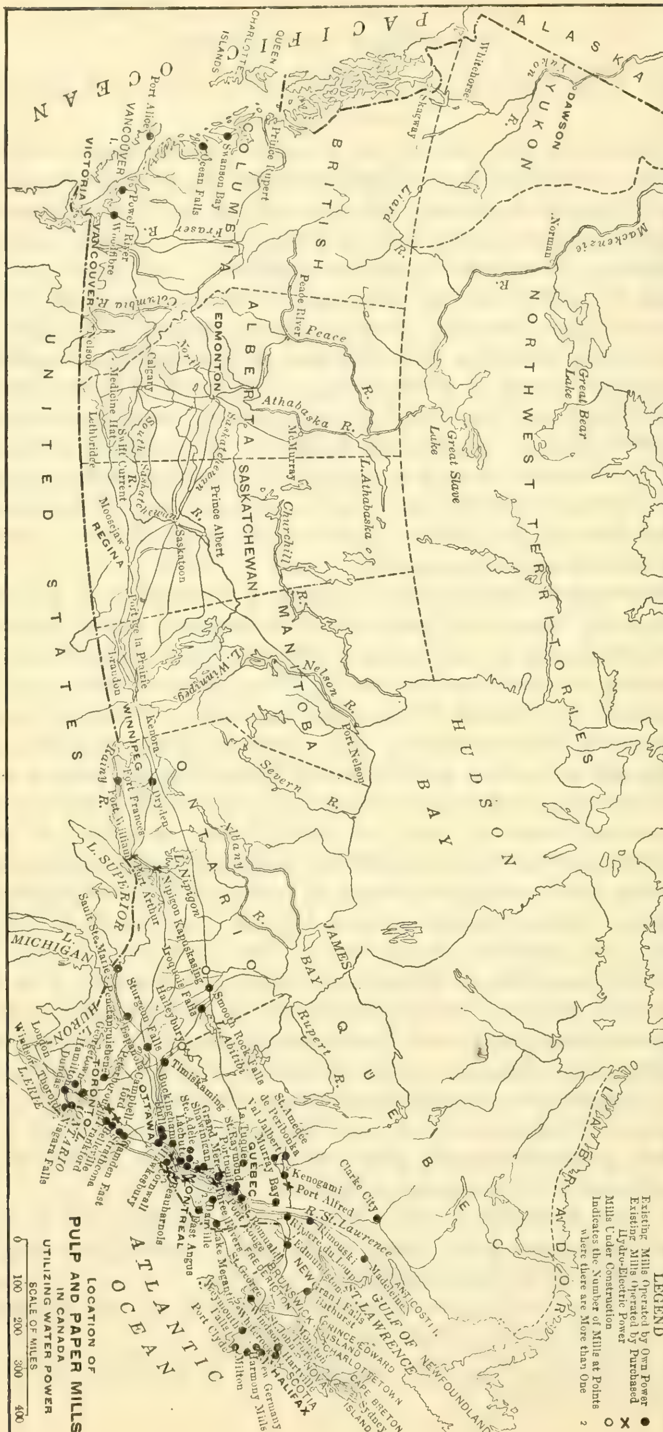

LOCATION OF
PULP AND PAPER MILLS
IN CANADA
UTILIZING WATER POWER
SCALE OF MILES
0 100 200 300 400
LEGEND
Existing Mills Operated by Own Power
Existing Mills Operated by Purchased Hydro-Electric Power
Mills Under Construction
Indicates the Number of Mills at Points where there are More than One

FIG. 1.

The energy derived directly or indirectly from water power for the operation of pulp and paper mills in Canada amounts to 637 080 h. p., of which 476 503 h. p. is controlled directly by the pulp and paper organizations and the additional 160 577 h. p. represents purchased hydro-electric energy. This paper deals with only the important relation of water power to the pulp and paper industry and does not include data on mills in which steam is used as motive power. In Canada, the use of steam power in this industry is very limited, being prompted in most cases by special conditions, such as operations where refuse from the manufacture of lumber can be used as fuel. The census returns of 1920 show a total steam-power installation in pulp and paper mills of only 62 400 h. p., and if the capacity of the three or four larger steam-operated mills in which special conditions obtain, is excluded, the remaining unit capacity is small.

Electric Drive in the Industry.—The electric drive is an important consideration. Of the entire water-power installation for the various mills, a total of 178 911 h. p. is converted into electrical energy before it is used to operate the pulp and paper machinery. The advantages of the electric drive are many; a uniform speed is assured, which is of primary importance in governing the quality of the product; it also allows the centralized operation of a large mill receiving power from several hydro-electric sources, and a closer study of power conditions, adjustment, and consumption is permitted. In a number of cases, the hydro-electric power is generated quite a distance from the mill in which it is used. In most instances, the mill is located at a water-power site and when gradual expansion has necessitated additional power, another near-by hydraulic site has been developed and hydro-electric energy is transmitted to the mill to permit centralized operation.

TABLE 5.—CHARACTER OF HYDRAULIC MOTIVE POWER IN PULP AND PAPER MILLS IN EACH PROVINCE.

Province.	Number of mills.	Horse-Power Installed and Purchased.					
		Turbine installation.			Purchased hydro-electric power.	Total hydro-electric Columns 4 + 6	Total from all sources.
		Direct drive.	Hydro-electric drive.	Total.			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
British Columbia...	5	27 975	20 825	48 800	......	20 825	48 800
Ontario.............	41	89 430	81 194	170 624	72 122	153 316	242 746
Quebec.............	54	159 900	64 512	224 412	88 455	152 967	312 867
New Brunswick....	3	2 368	12 300	14 668	......	12 300	14 668
Nova Scotia........	10	17 919	80	17 999	......	80	17 999
Canada.............	113	297 592	178 911	476 503	160 577	339 488	637 080

Operation from Purchased Energy.—In the Provinces of Quebec and Ontario, large power organizations supply considerable power to the pulp and paper industry. In Quebec, the Shawinigan Water and Power Company and

its allied organizations supply about 80 000 h. p., and in Ontario, the Hydro-Electric Power Commission and Toronto Power Company together supply about 55 000 h. p.

Motive Power by Provinces.—The method of producing power for the operation of pulp and paper mills is summarized by Provinces in Table 5. Although a large amount of water power is still used to drive the mill equipment directly from turbines, a considerable part is utilized by first converting it to electric energy for the more convenient electric motor drive.

Characteristics of Geographic Groups.—Table 6 illustrates the predominating features in certain districts into which Canadian mills may be arbitrarily grouped. Perhaps the greatest contrast exhibited in this table is between the class of mills found in the Niagara and Toronto, Eastern Ontario, Montreal, and Quebec groups, where a large number, the average capacity of which is small, produce much of the miscellaneous kinds of paper, whereas the British Columbia and more northerly groups in Ontario and Quebec comprise mills of large capacity, requiring much power to produce principally pulp and newsprint.

TABLE 6.—HYDRAULIC POWER IN PULP AND PAPER MILLS, CHARACTERISTICS OF VARIOUS GROUPS.

Groups.	Number of mills in group.	Horse-Power.				Average Daily Producing Capacity, in Tons per Mill in Group.		
		Own turbine instal-lation.	Purchased hydro-electric.	Total for group.	Total per mill in group.	Pulp.	Paper.	
							News.	Others.
British Columbia	5	48 800	......	48 800	9 760	147	89	6
North and Western Ontario	7	81 150	16 350	97 500	13 930	173	93	4
North Lake Huron	3	48 810	......	48 810	16 270	268	223	....
Niagara and Toronto District	17	6 943	42 142	49 085	2 890	33	18	18
Eastern Ontario	14	33 721	13 630	47 351	3 380	42	12	17
Montreal District and Western Quebec	15	36 558	3 345	39 903	2 660	28	5	17
Eastern Townships	6	30 152	8 500	38 652	6 440	90	18	24
St. Maurice Valley and ThreeRiversDistrict	6	21 110	66 350	87 460	14 570	268	111	27
Quebec City District	14	15 982	3 760	19 742	1 410	15	10	7
Lake St. John and Saguenay District	7	87 900	6 500	94 400	13 490	176	44	5
Lower St. Lawrence and Gulf	6	32 710	......	32 710	5 450	72	....	....
New Brunswick	3	14 668	......	14 668	4 890	93	....	....
Nova Scotia	10	17 999	......	17 999	1 800	23	....	....

General Conditions in Each Province.—The Province of Quebec is slightly ahead of Ontario in the pulp and paper industry. British Columbia ranks next, followed by New Brunswick and Nova Scotia. This industry has yet to be introduced in the prairie Provinces.

The Province of Quebec has 54 mills with a total of 312 867 h. p. The three largest mills are at Grand Mère, Kenogami, and Shawinigan, each of which requires about 25 000 h. p. Among other large mills requiring between

10 000 and 25 000 h. p., are those at Hull, East Angus, Brompton, Chicoutimi, Clark City, and Cap Magdelaine.

The Province of Ontario has 41 mills with a total of 242 746 h. p., including that at Iroquois Falls, reputed to be the largest, which requires 52 000 h. p. Another mill is located at Ottawa with 28 789 h. p., and mills requiring between 10 000 and 20 000 h. p. are located at Sault Ste. Marie, Espanola, Sturgeon Falls, Thorold, Fort Frances, and Fort William.

British Columbia has 5 mills with a total of 48 800 h. p., the two largest being at Powell River and Ocean Falls with respective installations of 24 000 and 20 550 h. p.

New Brunswick has 3 mills with a total installation of 14 668 h. p., and Nova Scotia has 10 mills with 17 999 h. p.

Future Power Requirements of the Industry.—It has recently been estimated that the present demand for pulp wood requires about 20 000 acres of Canadian forests per year and, following the trend of other commodities, this consumption will probably increase rapidly. Although the reforestation now being extensively conducted, will later help to remedy this depletion, it must be noted that from 50 to 100 years are required for suitable growth. Until full results are realized it will doubtless be necessary to extend wood pulp operations farther and farther north and the bountiful supply of Canadian water power in these regions will facilitate the fullest development of this industry.

MARINE BORERS

By W. G. Atwood,* M. Am. Soc. C. E.

Regardless of the enormous damage done by marine borers for centuries, they have been given very little systematic study. The *Transactions* of the Society contain four papers on the subject.†

The paper by Mr. Snow is a scientific study of the various borers themselves, whereas the other papers treat largely of methods of protection from their action. In various papers on harbor construction, many references to the subject are also made.

As far as is known, the studies now being carried on in the United States by the National Research Council, and in Great Britain by the Institution of Civil Engineers, are the first attempts to solve the economic problems involved in harbor construction in salt water by the close co-operation of biologists, chemists, and engineers. Both organizations are studying the borers as well as materials, methods of construction, and methods for the protection of existing structures threatened with attack by them.

Marine borers are found in fossil form and have been the source of great economic loss ever since the first structures were built in or floated on salt water. They are mentioned in the Bible where, according to a German biologist, F. Moll, the following passage occurs: "As the worm the wood so an ugly wife destroyeth her husband," and the writings of many of the early Greek and Roman scientists contain references to them. In early times, the true classification of the borers was not recognized, and those of the teredo type were thought to be worms.

The destructive borers so far as identified, belong to two families, the *Mollusca* and the *Crustacea,* shown on Fig. 2. The teredo group belongs to the family of mollusks, as do the oyster and clam, whereas the crustacean group, allied to the lobster and crab, are represented by the limnoria, sphæroma, and other similar organisms. The mollusks are also represented by the pholas, martesia, and other forms in which the body of the animal is inside the shell like that of the oyster, instead of outside of it, like the teredo.

Of the two families of borers, the mollusks are probably the more dangerous, because they enter the structure through minute holes and do their excavating out of sight, whereas the crustaceans bore comparatively shallow holes of small diameter, honeycombing the surface. The work of the latter group, therefore, can readily be discovered by inspection.

The beginning of modern literature and study of these organisms dates back to the Sixteenth Century. This study was first brought about by the destruction of the dikes of Holland, just as the beginning of the study now going on in the United States can be traced to the rapid destruction between

* Director, Committee on Marine Piling Investigations, National Research Council, New York City.

† "*Teredo Navalis,* or Ship-Worm", by the late G. W. R. Bayley, M. Am. Soc. C. E., *Transactions,* Am. Soc. C. E., Vol. III (1875), p. 155; "The Preservation of Timber", by the late J. W. Putnam, Assoc. Am. Soc. C. E., Vol. IX (1880), p. 206; "Protecting Piles Against the *Teredo Navalis* on the Louisville and Nashville Railroad Company's Lines", by Richard Montfort, M. Am. Soc. C. E., Vol. XXXI (1894), p. 221; and "Marine Wood-Borers", by Charles H. Snow, M. Am. Soc. C. E., Vol. XL (1898), p. 178.

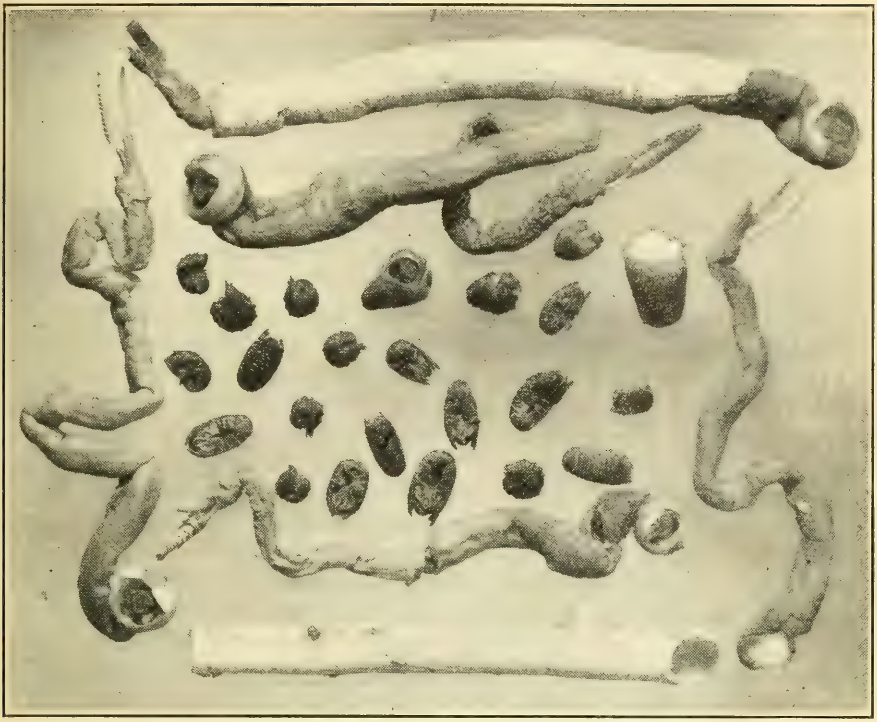


FIG. 2.—MOLLUSCAN AND CRUSTACEAN BORERS.

FIG. 3.—SOME ROCK AND WOOD-BORING MOLLUSKS.

1918 and 1921 of the structures in the upper part of San Francisco Bay. The destruction in Holland was caused by the species, *Teredo Navalis*, and, unfortunately, the name of this particular species covers, in the minds of most engineers and many scientists, all molluscan borers of this type. For this reason, statements as to the presence of this most destructive species must be looked on with doubt, unless the identification has been made by a competent biologist.

It is thought that the molluscan borers do not obtain any nutriment from wood or stone, but that they bore only to obtain shelter. Their food is obtained from the plankton of the sea in the same manner as that of the oyster and clam. The source of the food supply of the crustaceans is more obscure, but it seems probable that some of them obtain nutriment from the wood. The facts as to the food supply of these animals have an important bearing on the measures to be taken for protection from their activities. If chemical means are used, some poisons would be valueless if the organism did not digest the impregnated wood.

The teredo and *Xylotrya* (*Bankia*) are the most destructive of the boring organisms of wide distribution in the United States. They excavate and line, with a calcareous shell, burrows in the wood as shelters for their long worm-like bodies. The excavating is done with the shells which are on the head of the animal at the inner end of the burrow. These shells are actuated by powerful muscles and differ in thickness, shape, and character with the species. Some species have file-like teeth, whereas others have teeth like a wood rasp. The gills and digestive organs are immediately behind the shells, and the body reaches back to the minute hole through which the animal entered the timber. This end of the animal is equipped with two organs, the pallets and the syphons. The structure and shape of the pallets differ in the different species, and the characteristics of these organs form the most important means of identification. The pallets of all species have some common characteristics of form and all serve the same purpose. Each pallet is concave on the inner and convex on the outer surface, and when brought together they form a cone with the point outward. Ordinarily, the pallets project from the wood into the water and are separated. When disturbed, the animal brings the pallets together and pulls them in, thus closing the hole and shutting out enemies and harmful material.

The syphons are two muscular tubes normally extended between the pallets outside the timber. When in this position, a constant stream of water carrying food passes in through the incurrent syphon and a corresponding stream carrying the body wastes and the saw-dust resulting from the boring, passes out through the excurrent syphon. The syphons of the *Teredo Navalis* extend from 1 in. to 1½ in. outside the timber, and a badly infested pile looks as if it was covered with grey moss. When the animal is disturbed its syphons are retracted inside of and protected by the pallets when they are closed, and no sign of the presence of the animal is shown outside the timber.

The rate of boring and of growth of the body of the animal is the same, so that the burrow is always filled. This rate varies normally from 1 in. to 2½ in. per month for the more common species. In the float of the New Jersey

Oyster Commission that was destroyed in Barnegat Bay in 1921 by the *Teredo Navalis,* there were 80 teredo per cubic inch. They were so crowded that they could not grow, but at 6 weeks of age they were about ¾ in. in length and sexually mature.

The food of these animals consists principally of the countless marine organisms known to zoologists as "plankton." Dr. C. A. Kofoid, Professor of Zoology of the University of California, states:

"The ocean in common with lakes and rivers produces each year a crop or rather a succession of crops of microscopic food known as plankton on the ocean meadows whose tonnage per acre and whose chemical composition compares with the forage crops of wild and cultivated lands."

The molluscan borers feed on this exclusively, appropriating it as it passes their doors. They never go foraging, except in the case of the free-swimming larvæ. The variation in the supply of this food is seasonable and is largely responsible for the variation in the activity of the borers. Although in infested territory there is generally sufficient food supply for the maintenance of life, there is not always enough to enable the borers to maintain maximum activity. The period of reproduction generally corresponds to that of ample food supply.

The life history of the *Teredo Navalis* and *Xylotrya* (*Bankia*) is fairly well known. The young of the *Teredo Navalis* are born as free-swimming larvæ, whereas the eggs of the *Xylotrya* are ejected by the female, fertilized, and the larvæ hatched in the water. From this time, the history of the larvæ of both species is the same. The Dutch naturalist, Sellius, states that in the body of a medium sized *Teredo Navalis,* he found 1 874 000 larvæ. The *Xylotrya* (*Bankia*) does not produce so many eggs and as their method of reproduction results in a much lower rate of survival, the *Xylotrya* (*Bankia*) is not as destructive as the *Teredo Navalis.* The larvæ of both species are free-swimming for about a month, or until the weight of the shell is sufficient to sink them. When they come in contact with a satisfactory piece of timber, they attach themselves by means of a sticky thread and commence boring.

The rapidity with which these types of borers spread, can be readily appreciated when it is realized that a single, thoroughly infested pile may contain from 50 000 to 100 000 females, each producing more than 1 000 000 larvæ per year. The depth, in which these borers work is not known exactly, but it probably varies with the species. Both species under consideration will work to a depth in excess of 10 fathoms, and some species were dredged from great depths by the *Challenger* Expedition.

The martesia is another type of molluscan borer which is present, as far as known, only in the Gulf of Mexico. It greatly resembles the clam in appearance, the body of the animal being inside the shell, and is seldom more than 1 in. in length. This organism is very destructive, but as far as known, its range is limited. It differs from most of the other borers in the fact that thorough creosoting gives no protection. Very little is known of its life history.

The pholas, known on the Pacific Coast as the "rock-boring clam", somewhat resembles the martesia, except that it reaches a greater size. It bores

FIG. 4.—RESULTS OF LIMNORIA AND TEREDO ACTION ON PILING.

FIG. 5.—LIMNORIA ATTACK ON PILES ON ATLANTIC SEABOARD.

in wood little if any. It does however, bore freely in limestone, sandstone, and granite, as shown on Fig. 3, at the right and left, above. The fragments of a pine pile in the center show the attack of the martesia and at the bottom are burrow linings of the *Teredo Navalis*. The board on which the specimens are placed is mahogany bored by teredo on the West Coast of Africa. The presence of pholas in concrete has not been reported with certainty sufficient to indicate that it is a menace, but if it does attack concrete, it will readily be seen that a few holes in the vicinity of reinforcing rods will result in great damage. There are a number of other molluscan borers in American waters, but so far there is little to indicate that they have any great economic importance.

Next to the *Teredo Navalis* and *Xylotrya* (*Bankia*), the limnoria of the crustacean group is of the greatest economic importance. This animal has a flat body with fourteen segments and is about the size of a grain of rice. It has stout legs, some of which are equipped with claws like young lobsters. The eggs are carried on the abdomen of the female and the young, when born, are able to swim and walk as well as to bore. Although the rate of reproduction is much lower than in the teredo group, the proportion of young reaching maturity is much greater.

The limnoria chews the wood with its mandibles, making small galleries about $\frac{1}{16}$ in. in diameter and $\frac{1}{2}$ in. deep. In one specimen examined in San Francisco, there were from 200 to 240 burrows per square inch. It appears probable that the limnoria uses the excavated wood as food to a limited extent. On Fig. 4, *A* is a fragment of a Southern pine pile showing *Xylotrya* attack, cut between medium and low tide, after three years of service at Biloxi, Miss. *B* shows the results of limnoria on an untreated pile after two years of service at Boca Grande, Fla. *C* shows the results of limnoria and teredo action. The last specimen was secured in March, 1922, at Manhattan Beach, N. Y.

The sphæroma is another crustacean borer similar to the limnoria in its bodily structure and method of work. It is olive or reddish brown, marked with yellow, whereas the limnoria is greyish. This species reproduces in the same manner as the limnoria; there is, however, little knowledge of the life history of either species. The sphæroma is larger than the limnoria, and its burrows are frequently $\frac{1}{2}$ in. in diameter. Its activities are generally in the tidal plane, and it is not often found at the greater depths in which the limnoria and teredo work. This species does much less damage than the limnoria, but its activities are not confined to salt water.

The chelura, another species of the crustacean borer, is of less importance than the limnoria or sphæroma. Its work has the same appearance as the limnoria, and the two species are frequently found together. Thus far, the chelura has only been identified on the South Atlantic and Gulf Coasts.

Marine borers of one species or another exist in salt water practically all over the world, and there are some species which work in fresh water. They are of various sizes and differ as to their living requirements and capacity for destruction, but all of them, identified so far, are classified in either the molluscan or crustacean groups. The species of teredo living in the open

sea in ships bottoms, grows to be 6 ft. in length and 1 in. in diameter, whereas the *Teredo Navalis* is seldom more than ½ in. in diameter and 8 in. long. The *Xylotrya* (*Bankia*) is sometimes ¾ in. in diameter and 3 ft. long.

The living requirements of the different species are not known with certainty. It is thought that the *Xylotrya* (*Bankia*) requires a salinity of at least 20 parts per thousand and will not work effectively where there is considerable pollution by sewage or industrial wastes, although recent reports from Seattle, Wash., seem to indicate that it may have greater resistance to pollution than has been supposed.

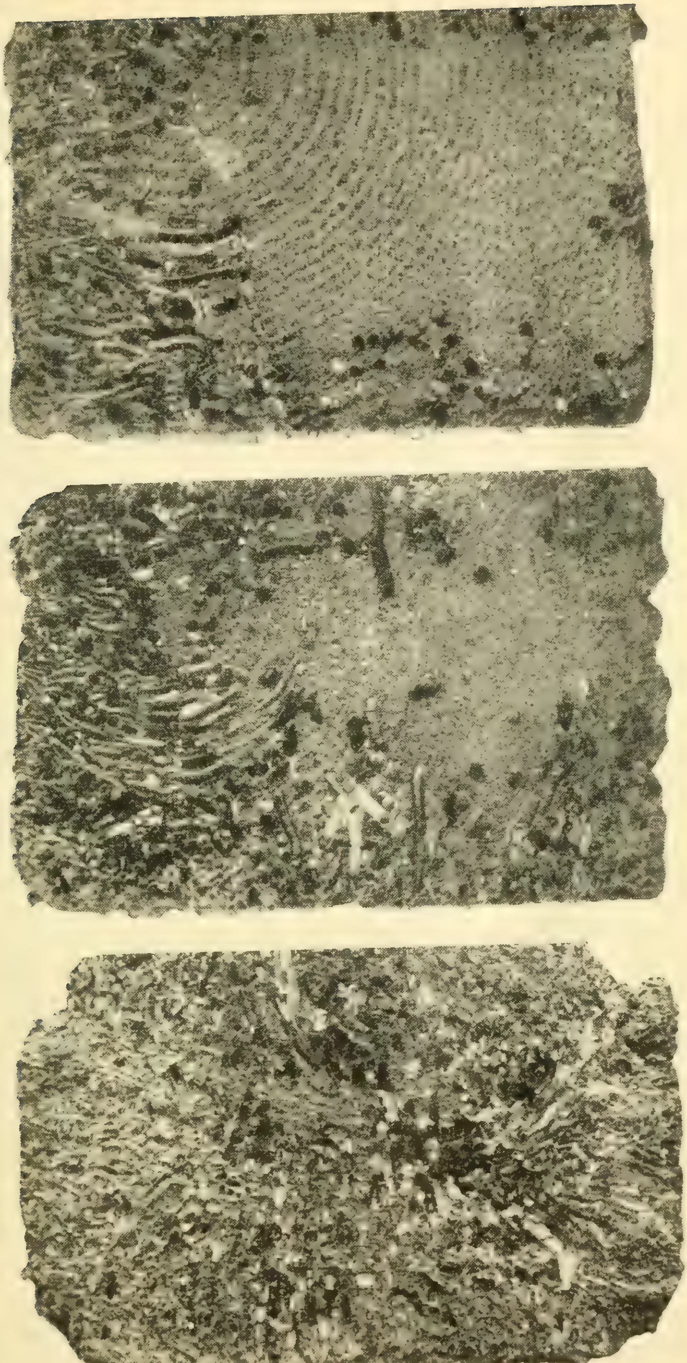
According to the older European reports, it appeared that the *Teredo Navalis* would not live in water with a salinity below 9 parts per thousand, but the exhaustive experiments, under the direction of the San Francisco Bay Marine Piling Committee indicate that this species will maintain a fairly active life with a salinity as low as 4 or 5 parts per thousand, and this result has been confirmed by experiments in the biological laboratory at Plymouth, England. It has also been demonstrated that this species will live at least 28 days in fresh water, although it will not work under this condition. If salt water is supplied after this 28-day period, the animal will open its pallets, extend its syphons and begin work. In fresh running water, it does not seem to survive much longer than a week. Experiments in the San Francisco Laboratory have also shown that the *Teredo Navalis* will live and work with full efficiency in water so polluted by sewage that there is no free oxygen, and putrefaction is taking place. These experiments are corroborated by the activity of this species in Oakland Creek which is very foul, and its immunity from the effect of industrial wastes is shown by its destruction of the wharves of the Standard and Shell Oil Companies where refinery wastes were discharged into the water which, with the piles, was covered by a scum of oil. The wharves of the Shelby Smelter Company, under which there was a discharge of copper sulphate, were also destroyed.

The crustacean borers have not been thoroughly studied, but it seems probable that the limnoria requires a fairly high salinity and is not seriously affected by pollution. The sphæroma is likewise little affected by pollution, but it will live and work in either salt or fresh water. The requirements of the chelura are little known. Fig. 5 shows the typical appearance of piles attacked by limnoria.

The distribution of the more common borers, as far as is known, is as follows:

The *Xylotrya* (*Bankia fimbriata*) is found from Nova Scotia to Florida, throughout the Gulf of Mexico, and from California to Alaska.

The *Teredo Navalis* is reported by many writers on all coasts, but many reports are of doubtful accuracy. It has been identified in the vicinity of New York City and San Francisco, and in Europe, from Norway to Italy, except in the Baltic Sea east of Kiel. Some species exist in the Eastern Mediterranean and Black Sea. It is reported that ships on the blockade of Sebastopol during the Crimean War, were damaged and some of them sunk by the *Teredo Navalis.*



a

b

c

FIG. 6.—ACTION OF TEREDO ON DOUGLAS FIR TEST PIECE.

The limnoria is found on all the coasts of North America and in practically the same locations as the *Teredo Navalis* in Europe. Its maximum activity occurs near the North Cape as well as at points farther south.

The limits of the sphæroma are not absolutely defined, but it seems to be of general distribution.

The chelura has been identified so far only in the South Atlantic and Gulf of Mexico.

Some harbors seem to be immune from the activities of some or all of the borers, and the reasons for this immunity are among those facts which the National Research Council is trying to develop by its investigation. Boston Harbor, for example, has been generally immune from teredo attack and although limnoria are present, no great damage has been done. In the paper presented by Mr. Bayley in 1874, previously mentioned, it is stated that a marked reduction in the activity of teredo had taken place in the Port of New York, in the three or four preceding years. It was thought by Mr. Bayley that this was due to an increase in the sewage pollution. If this was the correct explanation, it is probable that the *Xylotrya* (*Bankia*) was the species present, as it has been demonstrated that the *Teredo Navalis* lives in water with a much higher sewage content than that of New York Harbor. The activities of the teredo may be influenced by many other factors, about which nothing is known at present.

The rate of destruction by the molluscan borers does not seem to be greatly affected by the different kinds of timber in common use for construction purposes in the United States.

Fig. 6 shows the destructive action of the *Teredo Navalis* on a 6 by 8-in. Douglas fir test piece planted on July 1st, 1920, at the Southern Pacific Wharf at Port Costa, Calif. The first larvæ were discovered on August 4th, and the timber was removed on December 8th, 1920. Section *a* was 10 ft. 2 in., Section *b* was 6 ft. 6 in., and Section *c* was 6 in., above the mud-line. The contrast between inshore (right) and offshore (left) in the intensity of attack may be noted. The speaker had a wharf completely destroyed by *Xylotrya* in 18 months in Resurrection Bay, Alaska. W. H. Courtenay, M. Am. Soc. C. E., reports that a platform for carrying test pieces under a wharf at Pensacola, Fla., was destroyed in 30 days. Under favorable conditions, either the *Teredo Navalis* or the *Xylotrya* will destroy a 14-in. pile in 3 months.

The rate of destruction by the crustaceans is lower than that by the *Mollusca*. In waters where the limnoria is active, it seldom destroys a yellow pine or fir pile in less than a year.

The outbreak in San Francisco Bay is fully described in the valuable reports of the San Francisco Bay Marine Piling Committee issued in 1921 and 1922. As history repeats itself one may reasonably assume that similar outbreaks may occur at other places formerly immune.

Borers, probably the *Xylotrya*, had existed in the Lower Bay for many years, but were unknown in the vicinity of Mare Island and Carquinez Straits. The *Teredo Navalis* was first identified in 1914 in the long pile dikes pro-

tecting the channel to the Mare Island Navy Yard, and the borers apparently spread slowly through these dikes in the following years. Their activities became noticeable at other points in 1919 and, by the end of 1920, they had destroyed many structures near Mare Island and in Carquinez Straits, over a distance of about 8 miles, and had been found at Antioch, 25 miles up the Sacramento River. There is a strong tidal current through Carquinez Straits, which undoubtedly aided materially in the distribution of the larvæ.

Previous trouble with borers had not been experienced at the Mare Island Navy Yard and, consequently, the Navy Department had started to build a pile highway bridge between Mare Island and Vallejo, using unprotected timber. A few days before this bridge was to be opened for traffic, it was discovered that a number of the piles were eaten off and hanging from the drift-bolts. It was necessary to re-drive the entire structure with creosoted piles. Engineers for corporations owning structures in this territory estimate that the cost of repairs of damage caused by borers to the end of 1921 was more than $15 000 000. The history of this attack clearly shows that previous immunity does not justify the assumption that such immunity is permanent. Eternal vigilance is the price of safety.

Since the beginning of history, efforts have been made to protect structures from these organisms. The Phœnicians and the Vikings charred their ships and painted them with pitch, and the galleys of Troy were sheathed with lead. The writer has recently received letters from inventors and others who think they have discovered something new. Frequently, investigation shows that these "new" ideas have been tried by the Ancients. It is necessary, therefore, that harbor engineers seeking to protect structures from the ravages of borers should thoroughly familiarize themselves with the history of the borers and the attempts to secure protection from them.

The Forest Products Laboratory of the U. S. Department of Agriculture collected a great amount of data on methods of protection and, in 1913, an exhaustive report was prepared by Mr. A. K. Armstrong, which, unfortunately, was not published. The Committee on Marine Piling Investigations of the National Research Council is continuing this study and hopes to publish the results soon. This report divides protective methods into three general classes: The first includes reports on the charring of timber, the use of built-up piles and of unbarked piles. None of these methods has any permanent value. The second includes protection by mechanical means and the third by impregnation with various chemicals.

The second method is subdivided into painting or coating with paint compounds, protection by metal sheathing, earthenware pipe, pipe manufactured of other material, concrete, or an elastic or supposedly elastic coating. On Fig. 7, *A* is a section of a Douglas fir pile taken from Seattle Harbor after 4 years of service. This pile was creosoted, but very imperfectly. *B* shows a section, 3 ft. above the mud-line, of an untreated Douglas fir pile, after 1½ years of service at Vancouver, B. C., Canada. The pile had tight bark when driven. *C* shows a section of an untreated Douglas fire pile, 6 ft. above the mud-line, after 1 year of service at Vancouver. Surface treatment with paint

FIG. 7.—DOUGLAS FIR PILING AFTER FOUR YEARS' SERVICE.

or other material is damaged or destroyed by checking from rough handling during construction or by the abrasion or impact of floating material after it is in place. This method, although it may give temporary protection, is not permanent.

The metals used for sheathing have generally been lead, rolled iron, copper, zinc, several alloy metals, cast iron, and the process of nailing developed in Holland. All these metals corrode, and some of them, like copper, are of sufficient value to render them liable to theft. Any of these sheathings is efficient as long as there are no openings in the coating, but as soon as holes appear, the covering loses its value. The nailing process consists of driving the pile full of large-headed nails so that the surface is covered by the heads. Like other sheathing methods, it is expensive and although reported to have value as protection from the teredo, the limnoria is reported to dig out the nails and open a way for the teredo.

Concrete and the various pipe coverings are effective as long as no breaks in the surface occur and the pile is covered from the mud-line to a little above high water. A number of concrete coatings have failed, some on account of defective concrete and others because the mud-line was lowered and the borers cut off the pile between the new mud-line and the bottom of the covering.

The process of wrapping piles with a fabric impregnated with asphalt or similar material results in a pile that will resist attack until an opening is made in the coating. It is difficult to drive a pile without breaking such a coating and still more difficult to prevent damage by floating objects after it is driven.

Impregnation has been tried, many metallic salts and other supposedly poisonous chemicals, as well as creosote and mixtures of creosote and other materials, having been used. Thus far, creosote seems to give the best protection, but creosote is a trade name and does not indicate a product of fixed character. It is not known what constituent or fraction gives the protection, nor why good creosote protects timber for a time. There are two theories as to the cause of immunity from attack of some creosoted piles, one that the creosote contains a poison and the other that there is some constituent the emanations from which prevent the larvæ from landing on the timber. These theories are now being studied at two or three college laboratories and the Forest Products Laboratory.

If the reason for immunity can be discovered, a distinct step will have been made toward the solution of the problem as far as creosote is concerned. Those who believe in the inhibition theory, point to the fact that the teredo will bore freely in creosoted timber after it reaches a little size and that the martesia does not seem to be affected by it.

Some structures built with creosoted piles have had a life of 30 years or more in badly infested water, but such cases are rare. Many structures have had short life when both the creosote and the treatment were good, but the surface was damaged in construction. Careless handling of creosoted piles is probably responsible for a large number of failures.

An investigation of the resistance of various timbers was also made by the Forest Products Laboratory. It was not found that any indigenous woods would resist borer action, except, perhaps, Palmetto and some of its relatives. These timbers have little strength and decay rapidly above water level, so the fact that they resist borers is of little importance from the construction standpoint. A number of foreign timbers, principally from the Tropics, are reported to withstand attack, but great confusion exists as to the botanical identification of the species and it is difficult to obtain facts.

The Greenheart of Demarara is shown, by many reports from foreign harbors, to have long life, whereas others report its failure after a few years of service. It was used in the lock-gate sills and similar places in the Panama Canal, but was a failure and has been removed. Many reports regarding Australian turpentine wood are favorable. A small quantity of this wood was used in a wharf at Victoria, B. C., and has given excellent results for about 8 years. A number of favorable reports have also been received from the British Colonial harbors. There are also a few unfavorable reports. In regard to experience with certain kinds of Eucalyptus, it may be stated that the report mentioned does not indicate that Eucalyptus is immune from attack.

The Committee on Marine Piling Investigations of the National Research Council, with the assistance of Engineering Foundation and the co-operation of the various Government departments and the owners of water-front property, is endeavoring to determine the biological and chemical factors of the problem. It is planned, first, to discover what species exist and where; what the salinity, temperature, oxygen content, and hydrogen ion concentration are, and their effect on the different species of borers. With the assistance of Government, university, and commercial laboratories, the Committee is trying to discover why one creosote protects and another does not. The possibility of securing protection by the use of other substances is also being studied. It is hoped that, when these investigations are completed, it will be possible to draw a specification for creosote that will permit the removal of all constituents not necessary for protection and of value for other purposes, and to leave a substance that will be efficient.

The Committee is also making a study of substitutes for timber construction with the hope of issuing reports which will be of economic value to all builders and owners of water-front structures. It is hoped that all engineers who secure specimens of borers or information pertinent to the investigation will assist by sending specimens and information to the office of the National Research Council, Engineering Societies Building, New York City.

THE ST. MAURICE RIVER FLOW REGULATION

By O. LeFebvre,* Esq.

In 1912, the Government of the Province of Quebec adopted the policy of regulating the flow of the rivers of the Province, where storage reservoirs could be economically built and the stored water used for power purposes. The St. Maurice River was the first stream on which this policy was practiced.

The St. Maurice River rises in a series of lakes about 1 300 ft. above mean sea level, and flows from the northwest across the Laurentian Mountains into the St. Lawrence at Three Rivers. The river is about 367 miles long, has a drainage area of 17 000 sq. miles, and is broken by many falls and rapids, the principal ones of which are the following:

Name.	Height, in feet.
Les Forges	12
La Gabelle	10
Les Grès	44
Shawinigan	150
Grand 'Mère	78
La Tuque	88
Rapid Blanc	212
Rapid des Cœurs	93
Rapid Allard	45

The Shawinigan and Grand 'Mère Falls are fully developed, and that at La Tuque is partly utilized. It is expected that the falls at Les Grès and La Gabelle will be developed shortly.

Timber is the principal resource on the St. Maurice. Logs are floated down the streams to the main river, and down the latter to the different mills. The number of logs cut has been steadily on the increase until 1921.

Natural Flow of the River.—The flow of the river has been recorded at Shawinigan by the Shawinigan Water and Power Company, and daily discharge records are available from 1900 to date. The average low-water discharge is 6 000 sec-ft. The lowest discharge recorded is 5 200 sec-ft. for about a week in March, 1901, and the highest, which was recorded May 16th, 1904, was 166 000 sec-ft.

The average depth of yearly run-off from the water-shed at Shawinigan for the period 1900-21 was 21.6 in., the maximum being 26.9 in., in 1907-08, and the minimum, 15.33 in., in 1906.

Power.—The power at Shawinigan is generated under a head of 150 ft. and the low-water capacity of the plant was 82 000 continuous h. p. The machinery was designed for the discharge available during eight months of the year and the Company was disposing of the power as primary and secondary power. The total power possibilities on the river at natural low-water periods was estimated at 40 000 continuous h. p., which could be almost doubled if

* Chf. Engr., The Quebec Streams Comm., Montreal, Que., Canada.

secondary power was used, but secondary power is seldom satisfactory to the customer and must be disposed of at a low price. As the demand increases, the companies on the St. Maurice look for additional power by a more regulated flow of the river.

In 1909, the power and lumbering interests organized the St. Maurice Hydraulic Company which was authorized by the Government to complete certain storage schemes on the Manouane River. Three small dams were constructed from 1909 to 1911 and the reservoirs thus created have a total capacity of 590 sq. mile-ft. The water from these reservoirs was used during summer low water and during the winter. The minimum flow at Shawinigan was thereby raised to nearly 8 000 sec-ft.

These Manouane reservoirs proved the feasibility of obtaining water from reservoirs 200 miles from the generating plant, even under most severe winter conditions. In 1912, the St. Maurice Hydraulic Company applied to the Legislature for authority to carry out storage on a much larger scale in the series of lakes which form the upper reaches of the St. Maurice River. The Quebec Government decided, however, that it would be better policy for the Province to complete the scheme, and the Quebec Streams Commission, therefore, was asked to investigate and report on the possibilities of storage in the upper lakes.

Two alternative schemes were considered: Five small dams, each controlling a series of lakes and giving partial control, or one big dam giving complete control. The latter scheme was favored and recommended by the Commission.

It was found that by building a dam near the head of La Loutre Falls, and raising the water 47 ft. above natural low water, the capacity of the reservoir would be 5 722 sq. mile-ft. The area of the water-shed was 3 650 sq. miles, and the proposed reservoir would have capacity for 19 in. of run-off from the basin.

After investigations at the site, plans were prepared and several types of dams were considered. The gravity type was recommended by Edward Wegmann, M. Am. Soc. C. E.

The design provided for 50 000 lb. per lin. ft. of ice pressure, acting at the spillway level. No ice has formed opposite the gate section within 50 ft. from the dam, and it is doubtful whether any great ice thrust has been exerted against the structure.

The dam is 240 miles from the St. Lawrence River and controls the water from a drainage area of 3 650 sq. miles. The aggregate area of the lakes forming the reservoir was 209 sq. miles under natural conditions. To-day, they form one single body of water with an area of more than 300 sq. miles.

The dam was completed in December, 1917, and has been operated to regulate the flow of the St. Maurice at 12 000 sec-ft. at Shawinigan since January 1st, 1918.

Additional Power.—The benefits to be derived from regulation were calculated from the flow curve of 1906, which was the lowest year for the period, 1900 to 1912. A duration curve was made and the water necessary to make up the deficit for a minimum flow of 12 000 sec-ft. was calculated. Distributed

uniformly over the whole year, the power increase at Shawinigan totals 32 250 h. p.-years. At Grand 'Mère, where the water is being used under a head of 75 ft., the power increase is one-half that at Shawinigan.

In order to ascertain whether the quantity of water available in the Gouin Reservoir would be sufficient for a regulation of 12 000 sec-ft. at Shawinigan, investigations have been conducted since the latter part of April, 1913, when flow records were kept at the site of the Gouin Dam. The quantity of water measured at the dam site was taken as the supply from the dam and that required at Shawinigan to increase the flow to 12 000 sec-ft. was taken as the demand.

As it requires from 10 to 12 days for the water from the reservoir to reach Shawinigan the calculations were based on a loss of 25% from evaporation and other losses. Similar calculations were made for a regulation to 14 000 sec-ft. The curves show that such regulation is possible, but if a loss of 25% should occur, the reservoir would not be large enough. Since the dam has been in operation, it has been noted that the loss is negligible, being only about 5% in the winter.

Discharge Control.—The discharge of the river is controlled at three points, namely, at Weymontachingue, 50 miles below the dam, at La Tuque, 155 miles from the dam, and at Shawinigan. The water level at Weymontachingue and at La Tuque is recorded daily and the information wired to the office of the Quebec Streams Commission. Similar information is obtained from the Shawinigan Water and Power Company regarding the conditions at Shawinigan and Grand 'Mère. The points of control are also provided with rain gauges. In this way, a good idea may be gained as to the period it will be necessary to draw on the storage.

Ground Storage.—By raising the water 40 ft. above natural high water at La Loutre, the different lakes form one body of water, more than 300 sq. miles in area. As a great deal of the area covered is pervious, much ground storage must take place. The natural run-off, as a rule, is a minimum in March. Before the water was raised, the average for the winter months of three years was as follows:

January	291 sq. mile-ft.
February	219 " " "
March	215 " " "

Since the reservoir has been operated, the run-off in March and February is much larger than in previous years, as shown by the comparison given in Table 7. This cannot be explained otherwise than by ground storage.

TABLE 7.

Months.	1919.	1920.	Average of 3 years before operations began.
March....................	450 sq. mile-ft.	785 sq. mile-ft.	215 sq. mile-ft.
February...............	284 "	751 "	219 "

Land Clearing.—The area flooded by the reservoir has been estimated at 100 sq. miles, most of which is forest. This flooded area was not cleared on account of the cost, but it is not expected that much of the floating dead wood will reach the dam.

Manouane Dams.—Mention has been made of the three dams on the Manouane River. These dams have been acquired by the Commission and are being operated together with the Gouin Dam for the regulation of the St. Maurice. The dams are of the ordinary wooden crib type, filled with stone, their sluice openings being controlled by stop-logs. The combined capacity of the reservoirs formed is nearly 590 sq. mile-ft. The combined drainage area is 1 250 sq. miles. The supply of water from the basin is, therefore, much larger than the capacity of the three reservoirs, which overflow in the spring and are generally emptied during the dry summer months.

Cost.—The cost of the whole scheme was $2 500 000, or $400 per sq. mile-ft. of water. The yearly revenue is at present $215 000, which will be increased when new water power is developed.

This regulation work has been a success and, the amount of power now generated on the St. Maurice River is nearly 500 000 h.p. Nearly 500 000 additional h.p. could be developed. It is believed that these works will make the St. Maurice River one of the most important sources of water-power on this Continent.

SHORE PROTECTION AND HARBOR DEVELOPMENT WORK ON THE NEW ENGLAND COAST.

By Frank W. Hodgdon,* M. Am. Soc. C. E.

The New England coast consists of ledges, sand beaches, and bluffs composed of glacial drift, and the beaches and bluffs are gradually washing away.

The sea acts in two ways: First, sand and gravel, stirred up by the waves, are carried over the top of the beach, thus filling the low land back of it and forcing the shore line inland.

Where the land back of the beach is high, the waves drift the material along the shore until a low beach with low land back of it is reached. Here, the material is either washed over the beach on to the low land, or gradually drifts into the sea and forms shoals, as at the southeasterly part of Cape Cod Bay where they extend more than a mile from the shore.

Many different forms of protective work have been used in the endeavor to prevent further erosion. In some places, timber bulkheads were built at or above the high-water mark. A number have been back-filled, but in almost every case the timber structures have been either broken down or undermined. The large islands which form much of the protection to Boston Harbor, were early protected with heavy granite sea-walls and rip-rap by the Federal Government.

In 1828, a wall was built to protect the headlands of Deer Island and, in 1843, one was built at Lovells Island. Walls were built later at the Brewster Islands. In 1871, walls were built at Point Allerton, Long, and Gallops Islands. These later walls on the outer shore are about at the high-water line and their foundations are about at mean sea level. The tidal range is about 9.5 ft. and the top of the wall is about 22.5 ft. above mean low water. The wall is 5 ft. thick at the top and 9 ft. at the base, with a footing 12.5 ft. wide. The face is of granite and the backing and footing are of concrete. Adjoining the wall at the level of its top a pavement, 15 ft. in width, of granite slabs has been placed on the fill to prevent wash from waves which break over the top. The beach in front of the wall is also protected with a rip-rap of granite grout. These walls, although requiring repairs from time to time, have effectively protected the cliffs from erosion.

At the bluffs in Scituate and Chatham, the Commonwealth has deposited heavy granite grout from the high-water mark to 12 or 15 ft. above it. Sections of this protection at the Scituate Third Cliff have been in place for 14 years. At Chatham, at the bluffs in front of the lighthouses at East and West Chop, on Martha's Vineyard, ridges of stone have been placed about at high-water mark for a considerable distance on each side of the light-house. This has been an effective protection.

At Cotuit and Osterville, on the southerly shore of Massachusetts, facing Nantucket Sound, the bluff which is about 10 ft. high, is being eroded rapidly by the action of the sea. The owners have constructed timber bulkheads along the shore just above high water and, at intervals of 30 to 50 ft.,

* Chf. Engr., Div. of Waterways, Massachusetts Dept. of Public Works, Boston, Mass.

short timber spurs or jetties have been extended, which have prevented the sand from drifting along the beach, and a barrier has been formed, which has stopped the sea from making further inroads. These structures require constant attention as they are usually built of 2-in. plank spiked to 4-in. square stakes, the posts of the bulkhead being of cedar, 6 or 8 in. in diameter. This work, although costing considerable for upkeep, has been effective. The water in front of these bulkheads is shallow for ¼ or ½ mile. The range of the tide is generally less than 5 ft. and the waves are not heavy.

To protect the beaches at various points along the shore, walls with spur jetties from 50 to 100 ft. apart, have been built of concrete. The walls are located on the crest of the beach or between the crest and the high-water mark and the jetties project 1 to 2 ft. above the level of the beach. These walls extend about 22 ft. above low water or 12 ft. above high water and are built with a lip projecting about 6 in. at the top to deflect the sea. On the Scituate shore, some of the first walls had no lip and extended only 18 to 20 ft. above mean low water. At this elevation, the sea broke over the top and in places, large quantities of sand and shingle were washed over the wall. The beach was thus reduced, enabling the sea to undermine the wall in places so that it collapsed. It has been rebuilt to the elevation of 22 ft. with a projecting lip.

The harbor improvements may be divided into two parts: The improvement and protection of the channels, and the construction of wharves and docks. In the larger harbors, the U. S. Government has enlarged and deepened the channels and protected the entrances.

Boston Harbor.—In Boston Harbor, the principal work has been the dredging of the channels and the removal of isolated rocks and extensive ledges. The material, which is mostly clay, gravel, hardpan, and rock, has been excavated largely with scoop dredges. At first, the excavated material was deposited in the harbor, but recently most of it has been dumped in deep water outside the harbor. Inside the harbor, a large quantity of material was used for filling at South and East Boston where the Commonwealth has undertaken large reclamation plans. There are three entrance channels in Boston Harbor. The original or southerly channel just south of Boston Light crosses the entrance of the harbor about at right angles to the direction of the current caused by the tide. It originally had a depth of about 18 ft. at low water and was partly obstructed by rock or large boulders, which have been removed. This channel has been dredged to a depth of 27 ft. at mean low water, with a width of nearly 1 000 ft. The Broad Sound Channel, which was next opened, has a depth of 30 ft. and a width of 1 200 ft.

The third or northwesterly channel extends straight from the sea into President Roads and has a depth of 35 ft. at mean low water and a width of 1 500 ft. President Roads is a large area with a depth of water exceeding 40 ft. at low tide, into which these three channels lead. Extending from President Roads to the wharves at the city is a channel 35 ft. deep and 1 200 ft. wide, which originally was not more than 18 ft. deep at low tide. The excavation was mainly of silt and clay with some hardpan and considerable ledge, most of

the rock being slate. The character of the bottom of the harbor is such that there is very little shoaling caused by shifting material. The currents generally are less than 1½ miles per hour.

Leading to various points in the harbor are a number of subsidiary channels which have been dredged to depths ranging from 6 to 30 ft. at mean low water. In the inner harbor, a large number of wharves were constructed at an early date and until about 1870 were practically all owned by private individuals. Since that time, the Commonwealth has improved the flats at South Boston and, later, those at East Boston.

About 600 acres of flats extend from the shore of South Boston from ½ to 1 mile and about 2 miles in length from the city to Castle Island. This area has been filled by the Commonwealth and its grantors, mainly with material excavated from the harbor channels, and on it are the wharf terminals of the New York, New Haven and Hartford Railroad, the Commonwealth Dry Dock, 1 200 ft. long, 35 ft. over the sill at low tide and 120 ft. wide in the entrance, which was built by the Commonwealth and sold to the United States Navy Department in 1919. Alongside this dock is the area sold to the United States Army on which the Army Base was erected at a cost of about $25 000 000. The Commonwealth Pier, which is used by the largest merchant ships, and the Fish Pier, on which is the greatest fish industry in the United States, are also located here.

The Commonwealth Pier is 1 200 ft. long and 400 ft. wide with a depth of 40 ft. in the slips at low tide, the mean range of tide being nearly 10 ft. The pier itself is constructed of a granite sea-wall, 16 ft. high, founded on piles which are cut off at mean low water. The area enclosed by this wall, which is 2 700 ft. long, is filled with material excavated from the docks. Outside the sea-wall is a pile platform 50 ft. wide covering the slope of the excavation from the bottom of the dock to the foundation of the sea-wall at low water. This slope, which is 1 : 1.5, is covered with rip-rap. On this, as a foundation, has been built a steel and concrete two-story shed with a heavy masonry front or head-house. On this pier, in addition to the spaces devoted to cargo, are accommodations for handling from 1 000 to 2 000 passengers at a time, with facilities for all the necessary examinations of the passengers and baggage. The passenger facilities are on the second floor, from which a viaduct leads to Summer Street.

The Fish Pier is a solid-fill wharf. The filling is retained by a granite wall 41 ft. high, founded on rip-rap deposited in a trench in the bottom of the harbor. The water in the slips alongside is 23 ft. deep at mean low water. The pier is 1 200 ft. long and 300 ft. wide. The vessels lie up against the granite wall, on the face of which are oak fenders. The surface of the wharf outside the buildings is paved with granite blocks on a concrete base and the buildings are of concrete. In addition to the stores for handling fresh fish, a large cold storage plant has been built in which the surplus fish are stored awaiting a market.

The wharves at the New Haven Terminal are similar to the Commonwealth Pier, except that the floors of the sheds are of timber instead of

concrete and the sheds are of wood instead of steel and concrete. All piles of the platforms in both terminals are of oak.

At the Army Base, the piles of the wharf, which support a heavy concrete floor, are of pine. The buildings are of concrete and steel. Those on the solid portions are supported on concrete cylinders sunk into the clay, and the two-story sheds on the wharf are on the pine pile foundations. The sheds on the wharf are connected with the building on the solid portion by bridges over the driveway and tracks between the buildings. This wharf is equipped with four cranes of the semi-portal bridge type each having a capacity of 4 tons at a distance of 29 ft. from the face of the wharf.

The early wharves in Boston Harbor were built of stone-filled timber cribs enclosing areas which were filled with earth. Granite walls were used later in place of cribs and, in order to secure a greater depth of water alongside, the solid wharves were extended by building pile piers. In some cases, the granite walls were built on pile foundations. Some of the pile piers or platforms were built with timber floors, but, in others, the piles were capped about at high-water level. Round poles were laid on the caps and were then covered with marsh sods. On this, gravel was filled to the level of the wharf which was 14 to 16 ft. above mean low water. The filling was held in at the face of the wharf by timber bulkheads tied back to the capping of the piles. The timber work and piles, except the bulkheads which retained the filling, were thus kept wet and did not decay, and the cost of maintenance was small. A few wharves were built with granite walls extending about 20 ft. below low water, but most of the walls were founded on hard bottom or on piles at about low-water level.

Other Harbors.—Massachusetts has a number of small harbors which have been improved by dredging the channels and anchorage basins and building breakwaters and jetties to protect their entrances. The principal work which was undertaken by the Federal Government was the construction of a harbor of refuge at Cape Ann. Here, a heavy granite breakwater was built to enclose a large deep-water bay, known as Sandy Bay, at the outer end of Cape Ann. Up to low water, the breakwater consists of a ridge of large blocks of granite quarry grout. The superstructure consists of a facing of large split dimension stone backed up with quarry grout. About 6 000 ft. of the substructure has been built and about 900 ft. of the superstructure.

The slope of the faces of the substructure is 1 : 2 and of the superstructure 1 : 1. The facing of the superstructure consists of blocks weighing more than 20 tons each. The top of the finished breakwater is 22 ft. above mean low water and is 20 ft. wide. As the stones are somewhat displaced in heavy weather, the maintenance of the superstructure may be costly. Owing to changes in means of navigation, there is now much less need of a breakwater in this locality, and it is probable that this one will not be completed soon.

On the sandy shores like those at the mouth of the Merrimac River, stone jetties have been built to confine the current and direct it so that a channel will be scoured through the bar. To confine the current and prevent the waves from washing sand through the jetty into the channel, these jetties have been built of a facing of granite quarry grout with a core of chip

stone. They extend out to deep water in order that the sand scoured out will be deposited there.

The Commonwealth has built a number of breakwaters to protect small harbors, such as Apponaganset near New Bedford and at Vineyard Haven on Martha's Vineyard. These breakwaters are ridges of granite quarry grout 5 ft. wide on top with side slopes of 1 : 1.5, the top being from 4 to 5 ft. above high water. These breakwaters protect anchorage areas used by small boats and yachts.

Because of insufficient funds, most of the work done by the Commonwealth cannot be completed at one time and, in a number of cases, it has been practically abandoned after being partly completed. This has given an opportunity to study the effect of the work in various stages.

In some cases, channels, constructed through sandy beaches, as at the easterly end of the Cape Cod Canal, have a long jetty on the side of the opening from which the sand drifts, and a short jetty on the opposite side. The sand is thus prevented from entering the channel and the beach back of the jetty is built up.

In some instances, the funds were small and a jetty was built on the leeward side of the opening, in which case, the current was relied on to scour a channel. This has resulted in a narrow channel through the beach, which to the leeward has built out and up, and shoals have formed in front of the channel. The practice of placing the jetty on the windward side of the opening and dredging the channel has been more satisfactory.

Cape Cod Canal.—The largest private undertaking in Massachusetts was the construction of the Cape Cod Canal. This project has been under consideration almost since the settlement of the country. Surveys were made from time to time up to 1860, when an exhaustive report was made to the State Legislature. From 1870 to 1889, many charters were granted by Massachusetts to build canals from Buzzards Bay to Barnstable Bay and, about 1880, two attempts were made to excavate a canal, both of which failed for lack of financial support. In 1889, the Boston, Cape Cod, and New York Canal Company was incorporated, which later secured the co-operation of Mr. August Belmont of New York City. On August 19th, 1907, the construction of a canal was begun, which was opened to traffic on July 29th, 1914.

The canal is 8 miles long, has a depth of 25 ft. at mean low water, a bottom width of 100 ft., and side slopes of 1 : 2 in the main portion of the canal. The bottom width of the easterly approach channel is 300 ft. and that of the westerly, or Buzzards Bay, approach is 150 ft. The sides of the canal are rip-rapped from 6 ft. below mean low water to 6 ft. above mean high water to protect the banks from the wash of passing vessels.

The canal is spanned by three draw-bridges having openings 140 ft. wide. The two highway bridges have a clearance of 30 ft. above extreme high water, that of the railroad bridge being 2.5 ft. The canal is electrically lighted throughout, and the draws in the bridges are operated by electricity.

The tidal currents in the canal are quite strong, the mean tidal range at the easterly end being 9.4 ft. and at the westerly end 4.2 ft. High water

at the westerly end is about three hours later than at the easterly end so that the direction of flow changes quickly. The velocity of the current is from 3 to 5 miles per hour in the narrow section.

The easterly entrance is protected by a stone jetty about 3 000 ft. long on the northerly side. The westerly end is so well protected at the head of Buzzards Bay that no jetties were required, but a channel about 6 miles long had to be dredged in the Bay to reach deep water, thus making the distance from deep water in Barnstable Bay to deep water in Buzzards Bay about 14 miles.

At each end of the canal, where the section widens, shoals occur, which are removed by dredging. That part of the canal above tide level was largely excavated by steam shovels and drag-line scrapers. The lower part was excavated mostly by dipper-dredges as the material contained many boulders. This material was dumped in deep water outside the canal. A small part was excavated by hydraulic dredges. This material was dumped on the marshes and other low lands on the bank of the canal.

Because of the swift current, the advisability of placing a lock in the canal was discussed. It was decided, however, not to install it, and the canal is being successfully operated.

DIFFICULT FOUNDATION PROBLEMS FOR PISCATAQUA BRIDGE AT PORTSMOUTH, N. H.

By J. W. Rollins, Jr.,* M. Am. Soc. C. E.

The Piscataqua River is not very long, but has great possibilities for trouble. The tidal flow through the 900-ft. channel at Portsmouth is very great, the ebb tide having at times a velocity of 8 miles per hour.

In 1917, the New Hampshire Legislature authorized the appointment of a commission to investigate the feasibility of the construction of a highway bridge across the river.

The Commission made a favorable report to the Legislature of 1919, and Governor John H. Bartlett of New Hampshire, advocated the construction of a bridge in accordance with the report. The Legislature appropriated $500 000 for its share of the cost of the bridge. The Maine Legislature of 1919 appropriated $500 000 for the work, and the Federal Government was also induced to appropriate $500 000.

Under the legislation enacted, a new commission was organized consisting of Secretary of the Navy Daniels, Governor John H. Bartlett, of New Hampshire, and Governor Carl E. Milliken, of Maine. Each of the Commissioners appointed an engineer to represent him, Secretary Daniels appointing Commander E. H. Brownell, U. S. N., M. Am. Soc. C. E.; Governor Bartlett, W. A. Grover, Assoc. M. Am. Soc. C. E. of Dover, N. H.; and Governor Milliken, Mr. Lewis B. Jones, Bridge Engineer of the Maine Highway Commission. Mr. Jones was killed later in an elevator accident in Portsmouth, and Walter H. Norris, Assoc. M. Am. Soc. C. E., Bridge Engineer of the Maine Central Railroad, was appointed to take his place.

The Board of Engineers decided that the Portsmouth end of the bridge should be at Daniel and State Streets, and that it should cross the river at approximately right angles to the Kittery side, on Badgers Island. In September and October, 1919, investigations were made of the bottom of the river at the selected site, and this work was continued in May, June, and July, 1920.

Owing to the contour of the channel, the flood tide is on the Kittery side of the river, and the ebb tide on the Portsmouth side. These tides, acting in different channels, form great eddies the force of which cannot be estimated. The normal rise and fall of the tide is 9 ft., and this may be greatly affected by heavy winds.

The river bottom is covered with a layer of cobble-stones and gravel under which is a stratum of soft clay or mud, 3 to 10 ft. thick; next, there is a layer of hardpan from 6 to 10 ft. thick, overlying rock. The hardpan is so dense that a 5-ton orange-peel bucket would not touch it, and in the excavation in caissons it had to be loosened with pneumatic hammers.

The borings for the piers and abutments were made with drills, by wash-borings, and with well drills, the latter being used for the final determination

* Pres., Holbrook, Cabot and Rollins Corporation, Boston, Mass.

on the piers. The borings and soundings for the Portsmouth Abutment and the North Pier were close to actual conditions as determined by excavation, the North Pier being on rock at Elevation — 80.

On September 14th, 1920, proposals were asked for the construction of the foundations and superstructure, in two separate bids. The two bids exceeded the amount available, \$1 500 000, and the contracts were not awarded.

The original plans called for piers about 100 ft. long, with large sloping ice-breakers on the up-stream end, with a double Strauss lift bridge of 300 ft. span. As the authorities were anxious to complete the bridge, further studies were made to reduce the cost. A Waddell lift span was substituted for the Strauss lift, and the piers were re-designed and made symmetrical by omitting the ice-breaker. The result of these studies was that contracts were let, the substructure being awarded to the Holbrook, Cabot and Rollins Corporation, and the superstructure to the American Bridge Company. The work was awarded in November, 1920, and the speaker's firm began immediately to get plant and material on the site.

The great problem on this job was the moorings and anchors. No information as to the force of tides or water could be found, so the opinion of ship-builders was obtained. The result of these inquiries was that a force of 80 tons might result from the worst tidal condition. No anchors would hold against such a force; therefore, for the main up-stream and down-stream anchors, cribs about 20 ft. square and 15 ft. high were built and filled with gravel.

The cables used were of galvanized plow steel, 2½ in. in diameter, having a breaking strength of 200 tons. For the side anchors, two 40-ft. concrete piles, weighing 10 tons each, were used, with 1½-in. steel cables. Each anchor had two cables to the caisson, one fastened to the concrete air caisson, the other at the top of the first set of caisson sides, making a total of twelve cables.

The general design of the caisson was a concrete air chamber, 27 by 75 ft., with a 7-ft. clearance. The walls were 5 ft. above the deck of chamber, and, above that, regular wooden caisson side construction was used. The caissons were built on shore, where the launching space was very narrow and the water only 9 ft. deep at low tide. The launchways were placed on a grade of 2 in. to 1 ft., and it was planned to launch the caisson sidewise.

As no one seemed to know how the caisson would behave if it was launched with the 7-ft. air chamber open, it was decided to plank it solid across the bottom. No special provision for water-tightness was made, except to use matched planking.

The launchway had four double lines of 12 by 12-in. hard pine timbers as fixed ways, with a double set of 12 by 12-in. hard pine timbers as sliding ways. The fixed ways were spaced 4 in. apart and the movable ways had a 4-in. guide bolted between them, thus forming a fixed guide to keep the caisson straight. The fixed and movable ways were bolted together with 4 by 12-in. splices on the inshore end. The caisson was launched by cutting these 4 by 12-in. strips.

The concrete air chambers were designed as the foundations of the piers, and on account of the great depth of the water, the relation between the mass of masonry in the pier and the cubic area of the caisson, was very close. For

this reason, it was not considered safe to build the piers solid above the roof of the air chamber designed to carry the hydrostatic pressure to the full depth of water at the pier site. Consequently, the piers were built with side-walls 5 ft. thick at the bottom and 3 ft. thick at Elevation — 80, with three lateral cross-walls and one longitudinal wall in the center. Excessive pressure on the caisson sides was avoided with this distribution of concrete. This form of construction later proved to be a great aid in sinking the caissons. After some experimenting, the caissons were built to their full height, 66 ft. above the concrete. They were loaded to draw 40 ft. of water before being towed to the bridge site.

It was decided to build the North Pier first, owing to its more favorable position as to depth of water and tidal current. At this pier, the ledge was at Elevation ± 25 at the high corner and Elevation + 18 at the low corner, and was overlaid by 8 to 12 ft. of clay, with some hardpan. This overburden was dredged to the hardpan, about 3 ft. above the ledge. The caisson for this pier was built with one set of caisson sides, 22 ft. above the concrete air chamber. It was loaded to draw about 25 ft. of water and towed to the site.

The northerly side anchorages were on the ledge of Badgers Island, whereas all the others were crib or concrete anchors in the river. The flood tide struck the caisson about at right angles to its down-stream northerly side. No great strain was anticipated for the side anchors, as the ebb tide apparently was clear of the caisson. However, it was soon noted that the direction and force of the ebb tide had to be considered. The caisson would rest peacefully for a long time, and then some great swirl or eddy would strike it, and send it inshore, dragging the 40-ton anchors on the river side. With the outside line slacked, the flood tide would send the caisson back, bringing up hard on the inshore cables fastened to the ledge.

With 2 000 tons moving and "bringing up" hard on the inshore cables, it was evident that something must give way, as the side cables were not fastened to the caisson in a manner to withstand these shocks. The caisson, therefore, was taken back to the wharf and another set of sides 22 ft. high were built. A second set of fastenings was also built in it, and a second trip to the site was made.

The second attempt to land the caisson brought the same troubles as the first. The eddies on the ebb tide carried away the outboard anchors, moving the caisson 50 ft. inshore and landing it on the bottom of the river. It was finally decided that the bottom of the river was the only safe place for it.

With a hollow caisson, it was possible to flood the pockets with water and keep it on the bottom, and then, at low tide, pump out the water in one pocket and place the concrete. When a greater depth of water was needed to float the caisson, it was moved at high tide out into the deeper water. When the walls were built to Elevation 80, and concrete sufficient to hold the caisson in its true position on the bottom had been placed, it was moved out at high tide, and then sunk by filling the pockets with water. On the following slack tide, all the lines were "hitched up" and, at the next high tide, the caisson was floated by pumping out the water, lined up, and sunk again in its true position, which was within 3 in. of the line. Afterward, the caisson was kept on the bottom and sunk to rock.

The Portsmouth Abutment was built at the same time as the North Pier. A pier design was substituted for the Kittery Abutment. It looked simple on the plan—a sloping foundation on rock at an angle of about 30°, the front edge being shown at Elevation 74. Steel sheeting was driven below Elevation 74, 5 ft. in front of the line of the foundation, and the excavation was begun. Trouble soon developed, as the rock "dropped off" almost perpendicularly in the middle of the coffer-dam.

The sheeting was undermined and then driven down to low water. The excavation was made with a bucket, a sand-pump, and divers. The ledge was finally cleaned over the greater part of the area. Concrete was deposited under water, the entire excavation being filled to the sheeting. The excavation having been sealed, the coffer-dam was unwatered after a supplementary wooden dam had been built from the steel sheeting. The masonry was finished after a delay of several weeks.

At the South Pier, the bottom of the river sloped from about 1 ft. to 8 ft., and the rock, according to the soundings and borings, was at Elevations 29 and 26 on the inshore side, and Elevations 23.7 and 19.8 on the outer side. It was intended, therefore, to land the caisson on rock at about Elevation 25. Meanwhile, all the soft material possible had been dredged and the site of the pier had been leveled at about Elevation 30; this meant that inside would be hardpan and outside the original bottom, that is, soft material.

It was feared that the caisson, when landed, would either go out of level toward the river, or would slide out of position into the river. To avoid this, a window of crushed stone, about 3 ft. wide and 2 ft. higher than the hardpan bottom on the inside, was deposited along the outside edge. The caisson was towed to its site and sunk very near to position. On the next high tide, it was floated and pulled into a position 1 ft. inside of its true line. Within 24 hours after it had been landed, it had slid about 12 in. out into the river. It was again floated and placed 24 in. inshore and landed. It again moved about 12 in. and stopped. Rip-rap weighing 1 000 tons was then piled on the outside and no further movement took place. The water was pumped out and the concrete put in. The caisson was permanently landed about 8 in. out of position inshore.

The crushed stone kept the caisson about 1 ft. out of level inshore, until it was landed on hard bottom. At Elevation 26, the supposed rock level, no rock appeared. The sinking was continued to Elevation 20, and still no rock. The sides of the caisson were not high enough, and the shafting, locks, air, and other pipes, were too short, all of which had to be built up.

The contract did not require excavation to rock, and it was contended that at Elevation 20, the foundation on hardpan was suitable. The caisson was then 19 ft. below the original bottom on the up-stream end, and 12 ft. on the down-stream end.

The excavation was continued, and the cutting edge sunk to Elevation 16, 10 ft. below the designed level. The rock was cleared off in places to Elevation 9. As this additional work was done under an air pressure of 40 lb., the cost was excessive, being about $3 000 per ft. However, the entire contract was finished in March, 1922, seven months ahead of contract requirements.

DISCUSSION

By Messrs. Henry S. Adams, Frederic H. Fay, Wildurr Willing, and R. S. Patton.

Henry S. Adams,* M. Am. Soc. C. E.—Mr. Hodgdon has described much of the new marine work that has been done around Boston Harbor, and the speaker has had a great deal to do with some of the old work that has been built there. At first, the principal kind of construction was timber cribs filled with stone. The first record that the speaker has been able to find, Boston having been settled in 1632, was that of September 10th, 1673, when the town voted to "Errect a Wall or Wharfe upon the flats before the Town, from the sconce to Capt. Scarlet's Wharfe, or useing some other meanes for secureing ye said Town from Fire Ships in case of the approach of an enemie." This wall or wharf was described as being about 2 200 ft. in length, 22 ft. in breadth at the bottom, to be raised from 14 to 15 ft. in height, and to be 20 ft. broad on top for guns, and to be constructed of wood and stone. This barricade, or out wharf, as it was called, was built, and, in 1872, Atlantic Avenue was constructed over it. There is an old affidavit to the effect that it was built as a crib.

In 1710, Long Wharf was built, and is described in some of the old books as one of the longest in the world, being more than ½ mile, reaching from Chatham Row to low water. It was built in the form of a crib. The speaker has had occasion to pull up parts of that wharf, and the timber is as sound at present, apparently, as the day it went in. It was built of white pine.

"T" Wharf, which was an excrescence on the side of Long Wharf, was built in 1715. Part of that wharf was removed for placing the foundations for the Quincy Market Cold Storage, and the timber was found to be sound, in fact, there was some difficulty in removing it.

Long Wharf, in Portland, Me., was built in 1797 of crib work. When this wharf was removed in order to build another structure, a large proportion of the logs were found to be of white pine, and trouble was encountered because the timber floated. Logs from 20 to 24 in. in diameter were dug up, that were about 20 ft. below low water. The use of piles in the building of wharves began about eighty years ago. The speaker has had occasion to pull down some of those wharves, and evidences of teredo action have been found. The teredo is active in Boston Harbor as far as Lewis Wharf. Some of the timbers were full of them. The teredo and the allied limnoria are found as far as Constitution Wharf and the piles are badly eaten. Crib wharf construction has largely ceased since pile construction began, that is, south of Maine.

Frederic H. Fay,† M. Am. Soc. C. E.—Of the many harbors along the coast of Maine, the one of prime importance is that at Portland, where not only the chief seaport of Maine has been developed, but also an important winter port for Canada.

* Cons. Engr., Boston, Mass.

† Cons. Engr. (Fay, Spofford and Thorndike), Boston, Mass.

Portland Harbor.—Portland, located at the southwesterly end of Casco Bay, has one of the finest natural harbors in the world. It is almost on the open sea, but still is well sheltered; it has ample space for anchorage basins and a natural deep-water channel from the open sea almost to the shore line of its water-front.

The principal piers are within 3½ miles of the open ocean and the approach channel is so broad and straight that steamships calling regularly at this port frequently dispense with pilots and enter or leave the harbor at any time under the direction of their own officers.

Along the water-front of the city opposite that part devoted to overseas commerce is a dredged channel 35 ft. deep at mean low water, and 30 ft. deep for the remaining distance up Fore River. The character of the harbor bottom is such that this water-front channel may readily be deepened whenever conditions warrant. The dredged parts of the harbor require little maintenance, because of the almost entire absence of sediment in its waters. The mean tidal range at Portland is 8.9 ft. and there are no troublesome tidal currents.

Although Portland is the most northerly of the principal Atlantic ports of the United States, as well as the port nearest Europe, its harbor is notably free from ice and its water-borne commerce is not interrupted throughout the severest winter.

The strategic importance of this port has been recognized by the Federal Government and Portland has been made one of the strongest fortified harbors in the United States.

Railroads Entering Portland.—Portland is served by three steam railroads: The Boston and Maine, which operates three lines into the city; the Maine Central with its three main lines; and the Grand Trunk Railway of Canada.

The Boston and Maine Railroad connects Portland with the important manufacturing centers of New Hampshire, Vermont and Northern Massachusetts.

The Maine Central Railroad, by its own lines or by its connection with the Bangor and Aroostook Railroad, covers practically the whole State of Maine. The Maine Central's line through the White Mountains makes connections with the Boston and Maine, Canadian Pacific, and Quebec Central. Through its connection with the Canadian Pacific Railway, the Maine Central furnishes a route to Montreal, Que., Canada, Detroit, Mich., Chicago, Ill., the Great Lakes, and the greater part of Canada, especially the Canadian West.

The principal Atlantic terminus of the Grand Trunk Railway of Canada is at Portland and this port alone is used for its winter shipping for overseas traffic. The Grand Trunk affords a direct route to Montreal, Buffalo, N. Y., Detroit, Toledo, Ohio, Chicago, and the Great Lakes, and connects with the Grand Trunk Pacific Railway crossing the Canadian West. Grain is the principal commodity exported over the Grand Trunk docks at Portland,

nearly 43 000 000 bushels having been handled in the season of 1915-16. This is equal to the total grain shipments from the Port of New York for 1921.

During the winter of 1921-22, 17 000 000 bushels of grain were shipped through the Portland Terminal of the Grand Trunk and 99 trans-Atlantic and 37 coastwise vessels have berthed at its piers.

Portland the Natural Winter Port for Canada.—Portland is pre-eminently the natural winter port for the Dominion of Canada. It is only 297 miles from Montreal, and its connection with that city, *via* the Grand Trunk affords a rail route of relatively easy grades, particularly favorable for the movement of east-bound freight. The Canadian winter ports of St. John and Halifax, on the other hand, are, respectively, 481 and 842 miles from Montreal, *via* routes of steeper grade over which freight movement, especially in winter, is much more difficult and expensive. Had Maine been Canadian territory, Portland would no doubt be the leading port of Canada, or, at least, equal in importance to Montreal.

Portland's Belt Line Railroad.—Portland possesses one asset of great importance to the development of any port, namely, a belt line railroad which reaches every part of its water-front. This belt line is made up of trackage of the Portland Terminal Company (which is owned jointly by the Boston and Maine and the Maine Central Railroads and handles the traffic of both these roads in and near Portland) and of trackage owned by the Grand Trunk Railway. Along the important Commercial Street water-front of the city, each company has running rights over the tracks of the other, so that any wharf in this district is accessible on equal terms to all railroads entering the city.

Portland's Water-Front Developments.—Portland is well supplied with coal-handling and fuel-oil plants, most of which are up to date in capacity, equipment, and depth of water at adjoining berths. It also has suitable wharves for handling pulp wood, sulphur, and china clay used in the paper industry, not only of Maine, but of other parts of the country.

The remaining wharves along the water-front, with the exception of the Grand Trunk Terminal, are old and more or less obsolete, having been built in the days of sailing ships when Portland had an extensive trade with the West Indies. These wharves are now used either for coastwise shipping, or by business and manufacturing concerns, many of which could be accommodated with equal facility away from the water-front.

Grand Trunk Railway Terminal at Portland.—Until the present time, the only overseas terminal at Portland has been that of the Grand Trunk Railway System, comprising New, Ocean, Atlantic, and Galt Wharves, with two grain elevators with a combined capacity of 2 500 000 bushels and the supporting railroad yard. The first three of these wharves have transfer sheds and are used for overseas business. Although not of the latest type of pier construction, these wharves with their sheds are maintained in good condition and during the five winter months when navigation of the St. Lawrence River is blocked by ice, they accommodate a large volume of business with reasonable efficiency and dispatch. Until recently, harbor-line restrictions limited

the length of these wharves to about 500 ft., a length inadequate for the larger vessels now using this terminal. In 1920, the War Department established a new harbor line about 500 ft. out from the old one, making possible the extension of these piers so that in the future they may have a total length of 1 000 ft.

Portland's Need of Further Water-Front Development.—Within the last few years the need of increased water-front terminal facilities has been keenly felt at Portland. Certain steamship lines have sought to establish themselves at this port, but have been unable to do so because of the lack of facilities for the accommodation of their ships. Others already established have found it difficult at times to secure suitable berthing space. The Canadian Pacific Railroad is understood to have recently sought entrance to Portland over the Maine Central Railroad and if suitable water-front terminal facilities were available, some Canadian Pacific business would probably pass through this port. The Maine Central Railroad, however, like most other roads, has not been in condition financially to embark on further water-front improvements.

Public Development of the Portland Water-Front.—Recently, however, through the instigation of the Portland Chamber of Commerce, the need of further port development at Portland has been forcefully impressed on the people of that city and of the State at large. It is now recognized that port development should not be left entirely to railroads or other private interests, as has been the case at Portland heretofore, but should be, at least in part, under public control, not only to insure development on the broadest possible lines to the greatest benefit to the State and the city, but because, in addition to the direct benefits accruing to rail and water carriers, the community at large derives a substantial indirect benefit from such developments. In the City of Portland, several millions of dollars are spent annually by rail and water carriers in the purchase of coal, provisions, and other supplies from local dealers and for the wages of longshoremen, freight handlers, and others. It is recognized that for every ton of local freight shipped to and from the city there are many tons shipped to and from the district immediately tributary to the port, as well as the inland territory of the country. The people of Maine believe that with further development of the Port of Portland, making possible an increase in coastwise as well as overseas business, the industrial and agricultural development of the entire State will be stimulated, especially as the State has available much undeveloped water power which, in these days of high priced coal, may now be economically utilized to provide cheap fuel for industrial uses.

Through legislation passed in 1919, the State and the Cities of Portland and South Portland have jointly embarked on a policy of further development of the Port of Portland at public expense. The two cities have provided the site of the first of a series of publicly owned piers and the State is constructing such a pier alongside the Grand Trunk Terminals.

New State Pier at Portland.—The site for the new State Pier, which has been purchased and deeded to the State by the Cities of Portland and South Portland acting jointly through the State Pier Site District recently estab-

lished by legislative enactment, consists of Franklin Wharf, formerly owned by the Eastern Steamship Lines, Incorporated, and the berthing place of that company's coastwise lines, and of Galt Wharf, which was formerly owned by the Grand Trunk Railway. The State is now constructing on this site a modern pier 1 000 ft. long, to be equipped with adequate sheds and modern freight-handling equipment. For the present, the pier is designed to be used both for overseas and for certain coastwise business, and it will be adequate to accommodate the largest ships that will come to Portland for many years. The new pier will project nearly 500 ft. beyond the existing piers of the adjacent Grand Trunk Terminal and will extend to the newly established pier-head line previously mentioned.

In order to provide a slip of suitable width and depth between the Atlantic Wharf of the Grand Trunk Railway and the new State Pier, Galt Wharf, which was partly an old pile structure and partly a solid fill, has been completely removed, thus providing a slip 250 ft. wide with a depth of 35 ft. alongside the new State Pier. Ultimately, this slip may be deepened to 40 ft. if desired.

In the initial development of the State Pier, the existing Franklin Wharf is being utilized in conjunction with the new work, and the new pier is being built for a width less than that proposed for its ultimate development. This will afford a berthing space of 1 000 ft. along the easterly side of the pier, which will be used for overseas and Pacific Coast traffic. The westerly side of Franklin Wharf, as at present, will continue to be used by the Eastern Steamship Lines, Incorporated, for coastwise traffic, and that company is about to re-establish a freight line to New York City, which will be berthed at the westerly side of the new pier at the outer end of Franklin Wharf. Later, when conditions warrant, it is proposed to rebuild Franklin Wharf and to widen the State Pier so as to provide a complete new structure 1 000 ft. long, 320 ft. wide, with a least depth of 35 ft. of water on all sides.

The new pier will consist of creosoted Southern pine piles supporting a deck of reinforced concrete at the inner end and a timber deck elsewhere. The pier will have two transit sheds on its easterly side. The shed at the inner end is to be 90 ft. wide by two stories high and is designed primarily for trans-Atlantic shipping with accommodations for freight on the lower or main deck and quarters for saloon passengers and immigrants on the second floor. The shed at the outer end will be 60 ft. wide and one story high and designed for freight service only. On the westerly side of the new pier, a shed 60 ft. wide is now being erected for the New York freight service. At the easterly side, the cap-sill will be 27 ft. wide between the sheds and the fender cap, with a railroad track providing for the operation of a locomotive crane and with provision also for the installation later of semi-portal gantry cranes. Railroad tracks and trucking driveways are provided also in the middle of the pier.

Grain will be brought to the State Pier from the elevators of the Grand Trunk Railway Company by an extension to the grain conveyor system of that company through a modern fireproof gallery to be constructed by the State along the easterly side of the pier, the gallery being of sufficient size for the

installation of a second belt in case it should be found desirable to provide for the handling of grain from other railroads than the Grand Trunk. A working agreement has already been made between the State and the Grand Trunk Railway by which grain will be delivered to ships at the State Pier on the same terms and conditions that it is delivered to ships at the Grand Trunk piers.

Portland Port Authority.—The administration of this new publicly owned terminal is in the hands of a State Board, known as the Directors of the Port of Portland. The Board, created by legislation passed in 1919, is composed of five members, one of whom represents the City of Portland and was appointed by the Mayor of that City, and the others represent the four Congressional Districts of the State and were appointed by the Governor. This Board is the administrative agency of the port and on it is conferred the power to acquire property by eminent domain, to make all necessary plans for the comprehensive development of the port, take charge of and construct piers and other public works on State property, to operate such piers and administer all public works under their control, and to keep thoroughly informed as to the present and probable future needs of the port.

Wildurr Willing,* Esq.—Federal river and harbor works in the New England States from the Canadian border to Chatham, Mass., on the southeast point of Cape Cod, are in charge of the District Engineer of the Boston, Mass., District, a recent consolidation of the former Portland, Me., and Boston, Mass., Districts.

The following are the principal works included in the District: St. Croix River, Bar Harbor, Penobscot River, Rockland Harbor, Georges River (Thomaston Harbor), Portland Harbor and Saco River, Maine; Newburyport Harbor, Merrimack River, Harbor of Refuge at Sandy Bay, Cape Ann, Boston Harbor, Gloucester Harbor, Beverly Harbor, Salem Harbor, Lynn Harbor, Mystic River, Malden River, Dorchester Bay and Neponset River, Weymouth Fore River, Weymouth Back River, Plymouth Harbor, and Provincetown Harbor, Massachusetts.

The principal work has been the deepening of channels and anchorage basins by dredging and removal of ledge rock; the creation of artificial harbors by the construction of breakwaters; the deepening of bars at the mouths of certain rivers by jetties; and the preservation of shore lines.

Shore protection works on the part of the United States Government date back to 1824, and with peculiar historical fitness were first undertaken at Plymouth, Mass., for the protection of Long Beach.

Long Beach.—The existence of Plymouth Harbor depends entirely on the protection and preservation of Long Beach, which is a narrow strip of land that extends $2\frac{3}{4}$ miles out from the mainland in a northwesterly direction, nearly parallel to the shore of the Town of Plymouth and distant from it about 1 mile. It affords to the harbor its only shelter from easterly storms. For the protection and preservation of this beach, various works have been built from time to time, until, finally, they have proved efficient and successful.

* Lt.-Col., Corps of Engrs., U. S. A.; Dist. Engr., Boston, Mass.

The works originally undertaken for the maintenance of Long Beach were light temporary structures, of various designs, which may be described as follows: The bulkheads consisted of triangular frame or of cribwork of timber placed at intervals of 4 ft., covered with 2-in. plank, set in a trench 12 ft. wide and 3 ft. deep, the trench and frame being filled to the level of the ground.

The jetties consisted of a framework filled with brush and ballasted with stone. The groynes consisted of small stones intermixed with brush, and sometimes brush alone. They were built perpendicularly from the main bulkhead on the seaward side, spaced 50 to 150 ft. apart, and varied in length from 75 to 265 ft., aggregating 5 250 ft. Others have been built inside the bulkhead in places where most necessary. They were made by placing brush on the surface of the beach and piling beach boulders on it to a height of about 2 ft. for a width of 5 ft. The brush groynes were made by digging a trench 2 ft. wide by 2 ft. deep, and placing brush in it upright and as close as practicable. The brush is held in place by sand well rammed into the trench, and sometimes further protected by small boulders placed in a row along the sides of the groyne. The brush rises 2 or 3 ft. above the surface of the beach.

On account of the light design of these structures, repairs had to be made from time to time until finally rubble stone dikes were built, and they have fully served their purpose and continue in good order to the present time.

Boston Harbor.—The first sea-wall was started in 1825, to preserve Georges Island, an important site for one of the defenses of Boston Harbor. Sea-walls have been constructed at Deer Island, Castle Island, Rainsford Island, Lovells Island, Great Brewster Island, Long Island, Gallops Island, and Point Allerton. All these walls have been built by the Federal Government under the direction of the Corps of Engineers. From surveys made in 1820 and 1840, respectively, it appeared that 5.7 acres had been washed away from Great Brewster Island in the interval. This is about one-fourth of the whole island, at the latter period. The 1840 survey disclosed that the preservation of the islands from the wash of the sea was indispensable, as covers of the anchorages and roadsteads, and also to the maintenance of requisite depths in the channels. The aggregate length of these walls is about $3\frac{3}{4}$ miles, and the total amount expended in their construction and maintenance is about \$1 500 000.

Mr. Hodgdon has given an excellent description of the three main ship channels leading into Boston Harbor. The total of all Federal expenditures to June 30th, 1921, on these and the various subsidiary channels of Boston Harbor, including Chelsea Creek, Fort Point Channel, and the Mystic and Malden Rivers, Dorchester Bay and Neponset River, and Weymouth Fore and Back Rivers, has been \$12 734 167 for new work, and \$948 584 for maintenance. The total commerce in 1921 was 9 752 841 tons. On a capitalization of 4% and an estimate of \$40 000 per year for maintenance, there results a charge to the United States of 5.6 cents per ton.

Portland Harbor.—The second harbor in importance on the New England Coast is that of Portland, Me. The existing project for Portland Harbor provides for a commodious anchorage off the eastern end of the city, with a mini-

mum depth of 30 ft.; for the dredging of the greater part of the inner harbor to a depth of 30 ft., except for the lower part of the main harbor and its channel of approach, where the depth is to be 35 ft.; for a channel 30 ft. deep and 300 ft. wide in Fore River up to the upper Boston and Maine Railroad Bridge; for a channel 30 ft. deep and 300 ft. wide from the anchorage to the Grand Trunk Bridge at the mouth of Back Cove; for rock excavation to give a depth of 14 ft. between the Grand Trunk and Tukeys Bridges, and a channel 12 ft. deep and 300 ft. wide thence to the head of Back Cove; for the removal of two obstructing ledges in the main ship channel to a depth of 40 ft.; and for a stone breakwater about 1 900 ft. long on the southerly side of the mouth of the inner harbor. The project depths refer to mean low water. The mean tidal range is 8.9 ft., extreme 10.2 ft., although variations as great as 16 ft. have been observed under storm conditions.

The existing project executed by dipper and clam-shell dredges in material similar to that in Boston Harbor has been completed, except for the removal of ledges in the main ship channel, estimated to cost $100 000. The expenditures to June 30th, 1921, have been $2 271 386, and the annual maintenance is estimated at $3 000. The total commerce in 1921 was 2 369 881 tons. This results in a cost of 4 cents per ton.

Important breakwaters have been constructed at Rockland, Portland, and Bar Harbor, Me., and at Gloucester, Mass.

Rockland Breakwater.—The Rockland Breakwater extends from Jameson Point 4 350 ft. in a southerly direction. It consists of a mound of rubble with side slopes of 1:1 to a grade of 10 ft. above mean low water, at which grade the breakwater is 20 ft. wide. On this mound is a capping course of heavy split stone granite 15 ft. wide, bringing the top of the breakwater to a grade of 14 ft. above mean low water. The total cost of the breakwater was $615 000, and the annual maintenance is about $500.

The breakwater was completed in 1904, and stood undamaged until the winter of 1920-21, when some of the rubble mound on the seaward side slipped downward, the repairs for which are estimated to be about $9 000.

Bar Harbor Breakwater.—There is also a breakwater at Bar Harbor, extending from Porcupine Island to Dry Ledge and thence in a straight line to within 600 ft. of Mt. Desert Island, to protect the harbor from southerly storms. The breakwater was under construction when the World War broke out, and work was suspended on account of high prices and scarcity of labor. It has been estimated that about 15 000 tons will be required to bring it up to the grade of mean high water, and bids have been asked recently for the completion of the job.

Gloucester Breakwater.—The Gloucester Breakwater extends from Eastern Point over Dog Bar, 2 250 ft. in a northwest direction. It consists of a mound of rubble 31 ft. wide at mean low water, surmounted by a superstructure extending 17 ft. above the grade of mean low water, formed by two dry walls of heavy split stone, inclosing a core of rubble, capped by heavy stones forming a top course 10 ft. wide, the slopes of the rubble structure being, on the harbor side, 1:1.3, on the seaward side 1:3 to a grade of 12 ft. below mean low water, and 1:1.5 thence to the bottom. On the seaward side, the break-

water has an apron of heavy rubble rising to approximately 6 ft. above mean low water, the object being to protect the lower course of stone in the superstructure. The total cost was $410 097 and the annual maintenance is about $1 000.

The Sandy Bay Breakwater project has been recommended to Congress for abandonment. Only recently the remaining small balance in the hands of the District Engineer was diverted by authority of Congress to emergency use on the 1922 floods of the Mississippi River.

R. S. PATTON,* M. AM. SOC. C. E. (by letter).†—The problem involved in the design and location of engineering works intended to protect the shore from erosion by the sea is, in many cases, a peculiarly perplexing one. That problem involves, on the one hand, attack by a combination of forces each of which varies greatly from time to time both in its strength and in its direction; and, on the other hand, a resistance to attack determined by local factors of which the configuration of the shores, the character of the material composing them, and their accessibility to attack are merely typical.

This means that the engineer undertaking the erection of protective works must consider each locality as a unit. No adequate general rules can be laid down for his guidance. For example, studies now in progress of conditions along the New Jersey Coast indicate (the studies have not progressed sufficiently to justify a final conclusion) that each of the many inlets along that coast presents it own problem, and that protective works which would accomplish their purpose at one inlet might fall short of such accomplishment at the adjacent inlet, 10 miles distant. The writer does not mean to imply that there is any radical variation, in that short distance, in the nature of the attack from seaward. It seems more probable that the varying results noted are due to modifications of the seaward attack by the body of inland water.

It follows, therefore, that the confidence with which the engineer can undertake the construction of protective works will be in direct ratio to the thoroughness with which it has been practicable for him to determine the nature of the change which he undertakes to check, and the character of the forces producing it. Unfortunately, neither of these factors can be readily determined. In the United States, data on the subject of shore protection are meager, and such data as exist are not in a form readily accessible to the engineer. Consequently, many forms of protective works have been erected, which have failed to meet expectations, largely because local or private interests have not been in a position to undertake the extensive research necessary to ascertain the facts which under more favorable conditions would have formed the basis for the design of their structures.

The Federal Government has collected much data bearing on this subject. In practically all cases, this material has been gathered to serve some specific purpose other than shore protection, and its additional value in connection with studies of this character has been overlooked or ignored. It is fragmentary; one Bureau has collected a certain set of facts, a second Bureau another set. Each, by itself, may be of little value for this purpose; combined, they

* Hydrographic and Geodetic Engr., U. S. Coast and Geodetic Survey, Washington, D. C.

† Received by the Secretary, June 30th, 1922.

may be of great value. It is to be hoped that some day this material will be placed in shape for the use of the engineer. Meanwhile, however, the engineer derives little benefit from it because, in most cases, he either does not know of its existence, or, he does not know how to secure it.

It is not practicable for the engineer to obtain and utilize all this information. After eliminating a large part of it, a remainder exists, in most cases, readily obtainable at slight cost, which bears so directly on his problem that he would make a great mistake if he failed to take advantage of it if the project is of magnitude. The writer will endeavor to indicate briefly the character of this latter assistance which it is possible for various agencies of the Federal Government to render.

The engineer must seek the answers to two questions: (1) What is the nature of the change taking place? and (2), What forces are causing it?

Much progress toward the answer to the first question can usually be made by studying the topographic and hydrographic surveys made by the Federal Government. For the past hundred years, the Coast and Geodetic Survey has been making such surveys along the Atlantic Coast, and the frequency of re-surveys usually depends on the rapidity with which changes are occurring. For example, the New Jersey Coast is covered by three series of topographic surveys and an additional one by aerial photography, with from six to ten surveys of the various inlets. The Army Engineers also have made many surveys at localities where improvements have been proposed.

The surveys by these two organizations furnish a picture of successive stages in the development of the present shore, sufficiently separated to eliminate effects due to transitory causes, and thus enable one to deduce with considerable accuracy the general character of the evolution in progress.

The next step is to discover what forces operate and how they operate, to cause the changes observed. This is a much more difficult question than the preceding one, and the engineer can nowhere find the answer as he did in the first case. The best he can do is to secure data from all possible sources and then rely on his own judgment for the proper correlation of such data with the changes observed.

A great deal of valuable information can be obtained from persons having local knowledge, but information of this kind must be used with caution. It is usually fragmentary and superficial. Temporary effects and apparent causes are mistaken for basic factors. Therefore, the assurance with which such material can be utilized will be increased if the engineer can secure a background of fact against which to measure it. The material which the Federal Service can furnish is valuable as supplying this background.

The Weather Bureau has detailed statistics from which may be determined wind effects; the direction, frequency, duration, and velocity of prevailing winds and storm winds, respectively.

The Coast and Geodetic Survey can furnish detailed information regarding the tides and currents at many points along the coast.

The Bureau of Lighthouses and the Coast Guard have made studies of this subject in connection with the need for protection of their stations.

which contain information of value. In addition, the employees of those Services stationed at various points along the coast will be found to be particularly well informed regarding weather, currents, and waves, and their effect on the shore line in their immediate vicinity.

There is still another important element in the assistance which the Federal Government can render. There are engineers in these various units of the Federal Service, whose normal work is closely related to this problem. The knowledge and experience they have thus acquired, if applied to studies of the kind here suggested, would aid materially in their solution.

The writer does not pretend to speak with authority for all Services. His experience has been, however, that they are uniformly zealous to serve the public in every possible way, and that they would gladly assist in this matter to the limit of their facilities. For example, to mention a single specific instance, the State of New Jersey, aroused by the alarming encroachment of the sea on its beaches, has instructed its Board of Commerce and Navigation to study the problem and undertake protective measures. That Board has organized an Advisory Board of Engineers to co-operate with it, which Board includes representatives of two Federal Services, the Army Engineers and the Coast and Geodetic Survey.

What the Government is doing for New Jersey, it will be equally willing to do for other States.

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TENTATIVE SPECIFICATIONS FOR CONCRETE AND REINFORCED CONCRETE

Submitted as a Progress Report of the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete

Discussion*

By Messrs. Theodore Belzner, H. C. Morrison, and G. M. Williams

Theodore Belzner,† Affiliate, Am. Soc. C. E. (by letter).‡—Referring to the subject of water-proofing, it seems to the writer that consideration should be given by the Committee to the brick and asphalt method of water-proofing, as mentioned by George L. Lucas,§ M. Am. Soc. C. E., in connection with water-proofing structures below ground-water or sea level.

About 20 years ago, during the earlier construction of the Rapid Transit Subway in New York City, the writer had some experiences in stopping leaks in the side-walls, where the water-proofing behind it had been punctured and bulged, by the pressure of the surface water.

The method of repairs consisted of cutting out sections of the concrete, removing and replacing the water-proof paper, and placing brick dipped in hot asphalt in the section of concrete previously removed. This type of water-proofing proved efficient and, as far as the writer knows, no leaks have occurred since that time.

With reference to depositing concrete in freezing weather: In a number of cases, during the construction of some of the concrete piers for the elevated part of the New York Subway, in the winter of 1904, examination revealed that the concrete was frozen, and apparently, had not set. This was determined when the forms were removed, and parts of the concrete adhered to the forms. To overcome these conditions the sand and gravel were heated, the wooden

* Continued from March, 1922, *Proceedings*.

† Insp. of Steel, Harlem River, Manhattan, and Bronx Div., Dept. of Plant and Structures, New York City.

‡ Received by the Secretary, April 1st, 1922.

§ *Proceedings*, Am. Soc. C. E., March, 1922, p. 587.

forms were left around the piers, and the top surface of the concrete was covered with manure, which remained until the concrete had begun to set.

Later examination of these piers showed that the concrete had set and was in first-class condition, thus indicating that the precautions taken had been a great protection from frost.

The writer believes that if concrete can be kept at favorable temperature, while it is setting, excellent results can be obtained.

H. C. MORRISON,* ESQ. (by letter).†—The writer has read with interest the Tentative Specifications for Concrete and Reinforced Concrete, which have been submitted as a Progress Report of the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete.‡

He would assume from Sections 79 and 80 of Chapter IX that membrane water-proofing is the only one recognized or recommended. This is misleading, as there are several first-class companies that apply water-proofing treatments to either inside or outside surfaces. These treatments are not membrane applications and for more than ten years the method has proved successful under extreme conditions. These companies employ expert mechanics and operate under a guaranty, backed by a surety company bond when required. They are well incorporated, well rated, and are specified by some of the most eminent architects and engineers in the United States.

Why should a specification be written to exclude companies that have the reputation stated. Few companies that apply the different membrane treatments guarantee their work. Integral water-proofing is a failure. It tests well in the laboratory, but fails in field work. It does not take care of honeycomb concrete nor joints and expansion cracks in concrete. For a number of years, the writer was Water-Proofing Engineer for one of the largest manufacturers of integral water-proofing, and can state that on every structure in which it was used, and where water accumulated back of the walls and floors, leaks developed. The writer has also seen many membrane jobs, put on without guaranties, which developed bad leaks after several years. Materials that will remain water-proof, should be specified, and companies that guaranty their work should be recommended.

G. M. WILLIAMS,§ ASSOC. M. AM. SOC. C. E. (by letter).‖—The writer believes that at the present stage of the knowledge of the methods of proportioning concrete, the responsibility for the selection and specifying of quantities of cement and aggregate to produce a concrete of desired quality should be borne solely by the engineers in charge of the work. Further, it is due to the engineer rather than the contractor that the knowledge of concrete after years of general use is so greatly lacking. The first two alternative methods of proportioning, as detailed under Section 28,¶ "Proportioning", appear to be an acknowledgment on the part of the engineer that he has not sufficient information to specify the methods and materials required to result in a predetermined

* Pres. and Gen. Mgr., Contract Waterproofing Co., St. Louis, Mo.

†Received by the Secretary, June 23d, 1922.

‡ *Proceedings*, Am. Soc. C. E., August, 1921, p. 59.

§ Prof. of Civ. Eng., Univ. of Saskatchewan, Saskatoon, Saskatchewan, Canada.

‖ Received by the Secretary, July 10th, 1922.

¶ *Proceedings*, Am. Soc. C. E., August, 1921, p. 74.

quality of concrete, and indicate a desire to dodge the issue and throw the problem on the contractor. Too often in the past, the engineer has made no attempt to determine whether the concrete furnished equalled the quality specified and many specifications now in general use are contradictory, clearly indicating little knowledge of the concrete-making properties of the materials at hand.

The first alternative might have been copied directly from many of these contradictory specifications now in use. The assumption is almost general, that a 1:2:4 proportion will furnish a 2 000-lb. concrete at 28 days, yet in many localities the best materials available when used in such a proportion will not give a strength of more than 1 000 to 1 400 lb. A 2 000-lb. concrete has been assumed in design and a mixture has been specified which cannot furnish this strength. The failure of the engineer to use proper methods of tests and inspection has brought about a condition which should be remedied, but it is not clear why, at present, the responsibility must be taken by the contractor.

The third alternative, although relieving the contractor of the responsibility for the selection of the proportions to be used, is dependent on a table of proportions (Table 4)* which cannot be justified by actual tests. Such a table, to be worthy of inclusion in the specification, should furnish concrete which will closely approximate the assumed compressive strengths, but the variation in cements and aggregates in different localities will give concretes so different in quality that, in many cases, this table will not even serve as a rough guide. Its inclusion will give the user an assurance of accuracy which cannot be verified by actual tests and is certain to be regretted when the facts become generally known.

No tests should be required to disclose many of the absurdities in Table 4. For example, to result in a 1 500-lb. mortar, 1 volume of cement to 3 volumes of sand, graded 0 to 4, are required, whereas if 3.7 parts of coarse aggregate, $\frac{3}{4}$-in. to $\frac{1}{2}$-in., are added, 0.2 volume of sand can also be added without reducing the strength below the 1:3 mortar. Or, 6.1 volumes of $\frac{3}{4}$-in. to 3-in. aggregate may be added to the same mortar without a reduction in strength. In other words, it is claimed that a 1:3.1:6.1 concrete will have the same compressive strength as a 1:3 mortar, consistencies being the same in both cases. Many similar absurdities can be pointed out without resorting to compression tests.

A second objection to Table 4, as well as to certain other sections, is the use of the slump test as a measure of consistency for widely different aggregate gradations and cement contents. The slump test is of value in practical work where the same gradation of aggregate is being used, but should be given no standing whatever in the laboratory or in the comparison of different aggregates. For different gradations of aggregate or different cement contents, equal slumps do not indicate equal consistencies, mobilities, "flowabilities," or whatever term may be used to indicate the placeability of a concrete. Here, again, the inclusion of the slump test in the specification will give the engineer a false idea of its accuracy and importance, and for the purpose intended is worse than useless. For the reasons stated, it is not practicable to specify

* *Proceedings*, Am. Soc. C. E., August, 1921, p. 111.

definite slump values such as are given in Table 2.* The values shown may or may not furnish a workable, placeable mix, depending on the gradation and cement content. Definite values for consistencies or slumps can only be selected on the job for the particular materials and methods at hand. It will be a mistake to do more than describe the operation of the slump test and the limitation of its use for controlling consistency after the workability required is established by the condition of the particular work and aggregates at hand.

A third objection to Table 4, and one which would cast doubt on its usefulness even though the equality of the mixtures could be verified by tests, is the fact that different brands of Portland cement have different cement-making qualities. This difference in compressive strength may be as much as 25% and cannot be predicted by means of the present routine tests of cement. The concrete-making properties of the same brand of cement from the same mill will also vary with the length of time it has been in storage, so that the quality of the cement is a factor which has been ignored in compiling this table.

The writer believes that the specification for proportioning concrete should place the responsibility on the engineer, which in turn will require knowledge on his part of the concrete-making qualities of available cements and aggregates as well as minimum "flowabilities" which can be used on the work. Proportions can then be specified that will result in the required strengths for these consistencies. Provision should be made for change in proportions from time to time as indicated by the results of field tests, with payment to the contractor for excess cement used or deduction for less. More attention on the part of the engineer to tests and inspection will make it an easy matter to specify proportions and consistencies in advance and obviate most of the uncertainty which now exists.

Although most of the previous discussions have related to the first two alternatives which throw the burden of selection of proportions on the contractor, the inclusion of the third alternative will result in most serious difficulties, as Table 4 does not "indicate proportions which may be expected to produce concrete of a given strength under average conditions". It seems that the detailed information and test data obtained in computing Table 4 should be made public before serious thought should be given to making it a part of the proposed specification.

79.—Integral Water Proofings.—The writer believes that the exclusion of integral compounds so far as they may be proposed for water-proofing or damp-proofing is justified. Past experience, as well as data now being obtained from tests, indicates that these materials do not reduce the permeability. As far as the writer is aware, no test data which would indicate beneficial effects, based on properly conducted tests, have ever been made public by the manufacturers of such material. References to results obtained under practical field conditions tell only half the story and should be given little weight, as a rich mortar alone is impermeable for relatively high heads of water. Until positive evi-

* *Proceedings*, Am. Soc. C. E., August, 1921, p. 75.

dence can be produced to show that such compounds have a beneficial effect, they should not be given recognition in the specification.

D.—Concrete in Alkali Soils and Sea Water.—The provisions of Sections 87 to 91, under this heading, do not indicate knowledge of the conclusions reached from investigations of the past ten years with regard to the deterioration of concrete in alkali soils. Studies have shown that the best Portland cement concrete will be disintegrated when exposed to ground-water having a high concentration in sulphates. When quantities of sulphate salts are present, the advisability of using concrete may, in some cases, be doubtful and, in others, precautions should be taken to provide a rich concrete of low permeability with a thorough system of drainage which will effectually keep the salt water from the structure. Membrane water-proofing may be of assistance, but should be used only to supplement efficient drainage.

Section *D*, as worded, tends to give the impression that the use of 7 bags of cement per cubic yard will result in a concrete able to withstand alkali action. A rich concrete may prove more durable than a lean one, but it is not a guaranty of success.

As previously discussed, the slump test is not sufficiently reliable to permit such a specification as that given in Section 88. It is questionable whether many concretes having a 2-in. slump would be properly placeable. A dry consistency improperly compacted will prove more susceptible to alkali action than one having a slump of 5 or 6 in. In any case, the consistency should be the dryest that can properly be placed rather than an arbitrary slump value.

A brief statement of the conditions encountered in alkali soils will be of more value to the engineer than a detailed specification such as has been provided by the Committee.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

TENTATIVE SPECIFICATIONS FOR STEEL RAILWAY BRIDGES

SUBMITTED AS A PROGRESS REPORT OF THE SPECIAL COMMITTEE ON SPECIFICATIONS FOR BRIDGE DESIGN AND CONSTRUCTION

Discussion*

By MESSRS. J. B. FRENCH, BENJAMIN W. GUPPY, D. B. STEINMAN, O. E. HOVEY, HENRY GOLDMARK, HENRY B. SEAMAN, THEODORE BELZNER, WARRICK R. EDWARDS, R. S. CHEW, and H. M. MACKAY.

J. B. FRENCH,† M. AM. SOC. C. E.—The speaker has read the Tentative Specifications for Steel Railway Bridges and much of the discussion on them and feels that the extent and character of the discussions justify the appointment of the Special Committee.

The fact that the Tentative Specifications have been taken so largely from those of the American Railway Engineering Association should be considered as a genuine tribute to the excellence of the work done by that Association rather than as an effort to supplant it. Discussion should be welcomed by those who wish to keep the A. R. E. A. specifications up to date and make them of the widest application and usefulness.

It would be unfortunate to have such specifications regarded as final or to have their discussion limited to the body that formulated them, regardless of the excellence of the specifications themselves or the competency of the men who compiled them.

Considering the large number of clauses taken verbatim from the A. R. E. A. specifications, it might have been better to have printed those specifications in full and to have followed them with a series of reservations and recommended modifications. If so, there seems no good reason why this procedure cannot be adopted even now.

* Continued from May, 1922, *Proceedings*.

† Cons. Engr., New York City.

Such comments and suggestions as the speaker has to offer can be considered as applicable either to the Tentative Specifications or to the 1920 Specifications of the A. R. E. A. Without attempting to discuss the subject in detail, the following comments suggest themselves.

First.—Many matters of detail are specified rigidly, which, under certain conditions, cannot be complied with and which, in other cases, should preferably be left dependent on the conditions of the particular case. As an example of a requirement impossible of general observance, the clearance diagram (Fig. 1),* may be cited. The clearances specified, which are intended to clear a brakeman on the top or side of a box car, are desirable where practicable, but in grade separation work in large cities, such clearances would involve unwarranted expense. An alternative diagram should be given to cover the latter conditions. Again, the one live load rigidly specified is an example of a matter that should be left more flexible for the reason that many railroad structures, particularly in and around cities, are used almost exclusively for passenger traffic which is much lighter than the E-60 loading specified. If that loading is retained, the words "unless otherwise specified" should be inserted.

Second.—In regard to impact, the speaker is less concerned with the exact form of the formula used to establish the relation of impact to length of span than he is with the principle that the ratio of live to dead load shall be taken into account in its application. Some years ago, he was called on to design a large number of railroad bridges within city limits where solid floors were necessary and where fully ballasted tracks and concrete slab floors were considered to be desirable. In the preliminary studies, it soon became evident that unless the usual rules of design as regards unit stresses and impact were modified, this extra dead load would materially increase the weight of the main structures and increase their cost when compared with the old type of open-deck bridges. Considering the cushioning effect of the ballast and the added stiffness and solidity contributed by the concrete, which was thoroughly bonded to the steelwork, it seemed justifiable to modify the specifications by taking these facts into consideration and thereby reduce the weight of the steelwork. The following clause, therefore, was inserted in the specifications:

"In the case of main girders or trusses, and their supports, carrying fully ballasted track, one-half the dead load stress shall be subtracted from the full live load stress, before applying the impact formula."

It seems pertinent to state that the bridges designed in this manner have now been carrying very heavy freight traffic for more than 15 years and, at present, show no signs of weakness. The speaker would continue to use such a rule of design under similar conditions to-day.

Third.—The speaker believes that the unit stresses to be used in structural design should be determined by the known physical properties of the material rather than by the character of its use, and that variations in the conditions of use should be provided for logically by corresponding variations in the assumptions of the external forces to be resisted.

* *Proceedings*, Am. Soc. C. E., December, 1921, p. 687.

The unit stresses in these specifications are based on 16 000 lb. per sq. in. for axial tension. This value has in its favor the fact that in recent years it has been adopted not only in specifications for railroad bridges, but also in specifications for highway bridges and for the structural steelwork of buildings. However, it seems too low for all these purposes and the adoption of 20 000 lb. per sq. in. instead of 16 000 lb. would be justified by the known physical properties of structural steel and should be considered by the Committee.

A conclusive argument in favor of higher unit stresses is contained in the specifications themselves, in that an overload of 50% is provided for, and the rule to retain in service existing bridges the unit stresses of which do not exceed 24 000 lb. per sq. in. in tension, is regarded as safe and conservative.

Why not, therefore, increase the live load to E-75 and base unit stresses on a tension of 20 000 lb. per sq. in., or to E-90 and base unit stresses on a tension of 24 000 lb. per sq. in.

Fourth.—The use of structural steel and concrete in effective combination is not referred to in the Tentative Specifications. On account of the effectiveness of concrete as a protective covering for steelwork, its availability to fill spaces and exclude water, its fireproof qualities, and its strength and permanence, its use as a secondary material in the construction of steel bridges has grown steadily in favor and has assumed proportions warranting its consideration in specifications of this kind.

The rules for the design of reinforced concrete have been thoroughly discussed and developed, but where steel is the predominating material and concrete is used to protect and reinforce it, comparatively little has been done to develop or encourage rational design.

It seems obvious that where concrete is used in combination with structural steel, the more effectively the two are bonded, the more effectively the composite structure will serve its purpose and, if the materials are effectively bonded, the concrete will take its share of the compressive stresses and relieve the steelwork to which it is bonded. Consideration of these facts justify material reductions in the sections of steel parts embedded in concrete and carrying compressive stresses induced after the concrete has set and substantial economy can be accomplished by corresponding rules of design. The speaker has done this by the use of unsymmetrical beams and girders embedded in concrete, that is, rolled beams with bottom cover-plates only and plate girders with heavy bottom and light top flanges, and much of the work has stood the test of severe service.

The speaker wishes to express the hope that the Committee will continue its work, and that, in particular, the specifications for highway bridges may be submitted for discussion in the near future.

BENJAMIN W. GUPPY,* M. AM. SOC. C. E.—This amplification of a previous discussion† by the speaker of the Tentative Specifications for Steel Railway Bridges, is made at the request of several members of the Special Committee on Bridge Design and Construction.

* Engr. of Structures, Bost. and Maine R. R., Boston, Mass.

† *Proceedings*, Am. Soc. C. E., April, 1922, p. 901.

The scope and form of these specifications is questioned. Consider Article 336 as presented, "Provision shall be made for expansion and contraction at the rate of 1 in. for every 80 ft. in length". This rate has formerly been specified as $\frac{1}{8}$ in. for every 10 ft. of length. Others have specified that expansion joints shall provide for a variation of temperature of a definite number of degrees, but they have overlooked something. To specify that "provision shall be made for expansion and contraction due to variations in temperature and loading" will cover the subject completely. This can be followed by the rule—$\frac{1}{8}$ in. to 10 ft.—as a recommended short cut, but this rule should be accompanied by an explanation as to its derivation. It may also be advisable to call attention to the fact that the variations in temperature to which a structure will be subjected are not constant throughout the world.

Part 3, "Contract Stipulations", of Wait's "Engineering and Architectural Jurisprudence" is worthy of study as a model of the method of presenting information in a general specification. In this book, it will be found that where there is more than one method of attaining a given result, a number of suggestive paragraphs are grouped together and are followed by explanations and a discussion. It naturally follows that a general specification merges into a treatise on design minus the mechanics. It can also be conceived to be, on certain subjects, a digest and compilation of all existing specifications.

Sections A and B of the Tentative Specifications refer purely to business questions, dealing with office, and drafting-room practice. All information under these headings, that can be included in the specifications, saves just so much in the invitation to bid and there are fewer chances of errors of omission.

Such subjects as bidding on a group of bridges at widely separated locations, the conditions under which alternate bids based on contractors' designs will be considered, the number of free sets of blueprints the contractor will be required to furnish in advance of the delivery of the tracings of the shop drawings, errors and omissions on the contract drawings, etc., should properly be included here.

Article 4.—The statement that "drawings shall govern in cases where they are not in agreement with the specifications", should be qualified by the following phrase, "only when specifically noted on the drawings. Otherwise all errors and discrepancies should be referred to the Engineer".

The law seems to have been "side-stepped" entirely. It is realized that a compilation of all laws and ordinances relating to the design and construction of bridges is something outside the scope of these specifications, yet there should be a paragraph to call the attention of engineers forcefully to the fact that such laws exist and must be observed.

Article 13.—Any clearance diagram included should be presented merely as a recommended diagram to be followed where it does not conflict with the law or in the absence of specific instructions. In thickly settled localities, there necessarily must be modifications in clearance often requiring legislative approval, otherwise the cost of furnishing certain facilities would be prohibitive.

Article 15.—Unless the floor of the bridge is planked, ties should be spaced far enough apart so that one's foot will not get wedged between them. The minimum that can safely be used is about 6 in., and 10-ft. ties are long enough, provided an occasional tie is extended and a sidewalk is built outside the guard-stick. These walks have become common in yards and are being called for more and more frequently by Safety First Committees. A floor of 12-ft. ties, without a sidewalk, does not afford a good passageway alongside a train, especially when coated with snow and ice.

Article 105.—The reduction percentages to be applied to loads for multiple-track bridges should be such that the total live load plus the impact minus the reduction, will not be less than the live load without impact. Such bridges in or near yards and terminals will be loaded on all tracks more frequently than similar bridges on the road.

Referring to Section 2, Unit Stresses, after the correct relationship between the various stresses has been determined for each class of material, the question of the actual pounds per square inch to be used can be left to individual judgment.

Article 206.—Should not the combined fiber stress be limited to a tension of 16 000 lb. per sq. in. and the proper reduction made for compression?

Referring to Section 3, Details of Design, there will always be a difference of opinion concerning the value of certain details. In this section particularly, a compilation of the varying clauses of different specifications will prove of value, especially if accompanied by a full discussion and explanation of each requirement.

In closing, it may be stated that local conditions exert such a great influence on the development of any design that they cannot be ignored in a general specification.

D. B. STEINMAN,* M. AM. SOC. C. E.—The speaker feels, as others do, that the discussions started by the publication of the "Tentative Specifications for Steel Railway Bridges", will prove stimulating and valuable to the Profession. Particularly noteworthy is the complete set of specifications† which Mr. Seaman has presented as a substitute. These specifications probably come nearer to being an ideal set of bridge specifications than any previously published, and Mr. Seaman merits the gratitude of the Profession for his contribution.

The speaker's ideas on some of the questions involved are recorded in his written discussion previously published.‡ In that discussion, the importance of designing bridges for ultimate loads with ultimate safe stresses was emphasized. Mr. Seaman has covered this requirement by specifying a 50% increase over the customary nominal loads and stresses, and thereby has achieved a striking advance over any previous standard specification for bridge design. The retention of this feature in the specifications finally adopted by the Society will be an important achievement; it will yield balanced designs conducive to the longest possible life for the structure.

* Cons. Engr., New York City.

† *Proceedings*, Am. Soc. C. E., April, 1922, p. 946.

‡ *Ibid*, p. 889.

Mr. Seaman has directed attention to the impact specification proposed by the speaker.* This impact formula:

$$I = \frac{200}{l + 100} \times \frac{L}{L + D}$$

is based on the principle that a correct specification for impact should include the factor, $\frac{L}{L + D}$, as well as the factor of load length. This formula is the simplest thus far proposed to cover both these factors. At the same time, as shown in Fig. 17 of the speaker's discussion, previously mentioned, it yields values coinciding with the maximum results of impact tests from the shortest to the longest spans.

Many engineers have recognized the correctness of the foregoing principle, that the impact allowance should depend on the ratio of live load to dead load. It is generally accepted that the impact allowance should be less on ballasted-floor bridges than on open-floor bridges of the same span. Some designers make it a practice to take an arbitrary fraction (one-third or one-fourth) of the specified impact allowance when they are designing a structure which is to have a solid deck. The impact formula proposed by the speaker takes care of all these requirements: It is simple, scientific, and checks the tests. It automatically yields a reduced impact on bridges with solid ballasted floors and on bridges carrying a highway floor in addition to the railway tracks. It automatically increases the impact tax on very short spans and reduces that tax on very long spans (without making it zero). It automatically increases the impact tax on web members and counters. In conformity with test results, it yields impacts exceeding 100% for very short spans and makes automatic correction for the inertia resistance of the heavier sections in a given structure, as well as of the heavier structures in a given line. It automatically increases the impact tax on light members and light structures; and it is a partial inducement toward adopting heavier and more rigid construction. It automatically apportions the largest relative additional metal for impact to those members in which the live load bears the largest ratio to the dead load, thus contributing to the longevity of the structure under increasing loads. The formula is applicable without change or correction to all types of structure on a line.

These features appear to be sufficient justification for directing attention to this impact formula, and the speaker respectfully submits it to the future study and consideration of the Profession.

O. E. Hovey,† M. Am. Soc. C. E.—The speaker feels that it is proper and desirable for the Society to prepare a broad general specification for bridges.‡ Matters of minute detail should be avoided, leaving users of the specifications free to express their own preferences. He believes that such a general specification will be favorably received by the Profession.

There has been quite an extended discussion of various impact formulas, and it may be useful to comment briefly on some phases of the history of

* *Proceedings*, Am. Soc. C. E., April, 1922, p. 892.

† Asst. Chf. Engr., Am. Bridge Co., New York City.

‡ See discussion by the speaker, *Proceedings*, Am. Soc. C. E., April, 1922, p. 922.

their development and use. During the decade from 1880 to 1890, many American engineers began to use the methods of proportioning members that had been developed by Launhardt, Weyrauch, and others, based on the fatigue tests of Wöhler and Bauschinger in Germany and those of Sir William Fairbairn and the late Sir Benjamin Baker, Hon. M. Am. Soc. C. E., in England.

In 1885, the late Joseph M. Wilson, M. Am. Soc. C. E., Engineer of Bridges and Buildings of the Pennsylvania Railroad, issued a specification for wrought-iron bridges in which it was stated that members subject to one kind of stress, all tension or all compression, should be designed for working stresses, a, determined from the formula:

$$a = u \left(1 + \frac{\text{minimum stress in the piece}}{\text{maximum stress in the piece}}\right)$$

Members subject to reversing stresses were designed for working stresses:

$$a = u \left(1 - \frac{\text{maximum stress of lesser kind}}{2 \times \text{maximum stress of greater kind}}\right)$$

The value, u, depended on the kind of iron used, and was 7 000 lb. per sq in. for single-rolled iron plates and shapes in tension, and 7 500 lb. per sq. in. for double-rolled iron in tension for links and rods.

Although this method of designing produced a satisfactory distribution of material it was cumbersome, as each member and its details and connections, including rivets, required the use of a working stress, a, peculiar to the member. As a result of this fact, various attempts were soon made to apply corrections to the calculated stresses, so that by the use of a constant unit stress basis per square inch, the same, or a closely similar, distribution of material would be accomplished. These adjustments of the calculated stresses were called "impacts", but the speaker believes they had little or no reference to impacts due to the passage of moving loads. The formula* developed by the late Fred Thompson, M. Am. Soc. C. E., and first published in the specifications of the Southern Railway Company in 1894, was in the familiar form,

$$I = S \frac{300}{L + 300}$$

This convenient formula was at once adopted by the late C. C. Schneider, Past-President, Am. Soc. C. E., as simpler and more satisfactory than his own, and has been generally used in the United States, Canada, and India for many years.

The speaker feels that it was unfortunate that the stress adjustment was called "impact", and the use of this term may have misled some users of the method not fully advised of the history of its development.

In 1908, the speaker wrote a specification for bridges based on the fatigue method of design and found that by making the value of u, in the Pennsylvania Railroad formula of 1885, equal to about 9 000 lb. per sq. in. for structural steel, the areas of the main members of single-track bridges, up to 200 ft. span, became almost identical with those of the same spans designed by the use of the "impact" formula, previously given, using unit stresses based on 17 000

* See discussion by J. B. French, M. Am. Soc. C. E., *Transactions*, Vol. LXXV (1912), pp. 363 to 370.

lb. per sq. in. This fact tends to confirm his belief that, for practical purposes, the use of the so-called "impact" formula,

$$I = S \frac{300}{L + 300}$$

is mainly a convenient method of distributing the material in a bridge in order to conform practically to the fatigue method of design.

The real test of good design is the behavior of bridges under heavy traffic. When long service and low maintenance costs are considered, the speaker believes that bridges designed by the fatigue method have been more satisfactory, on the whole, than those designed by most methods. In view of the recent fatigue experiments, and studies now being conducted, he feels that this subject should be carefully considered in connection with the many observations of impact due to passing loads now available, before the definite adoption of a new impact formula.

HENRY GOLDMARK,* M. AM. SOC. C. E.—The speaker is much interested in Mr. Hovey's remarks on the historical development of bridge design. He has always felt that in an applied science, the study of its evolution is not only of much theoretical interest, but also of direct value in understanding the principles underlying present practice. In the case of bridge engineering, the history of the different methods for taking account of the greater effect of the live loads, especially of train loads, in comparison with the dead weight, is of much interest. Their greater influence on the stresses was realized at an early stage of bridge development, and various methods of design, with this basic idea, have been used at different times.

The earlier methods were frankly empirical, whereas the later ones are based ostensibly on theoretical considerations. It can hardly be said, however, that even the latest practice has an exact scientific basis.

The bridge specifications of the past forty years reflect the varying views held at different periods. In the earliest specification issued by the late Theodore Cooper, M. Am. Soc. C. E., the cross-sections were determined by dividing the sum of the dead and live load forces in each member by a permissible unit stress. To allow for the great effect of live loads in short bridges, a lower stress was specified for such spans. Although many good bridges were designed under this specification, there was a serious objection to this method of proportioning, because of the fact that the unit stress changes suddenly at a given span length, say, from 8 000 to 10 000 lb. per sq. in. Therefore, for bridges differing only 1 ft. or 2 ft. in length, there might be a considerable difference in the permitted stress. This was clearly illogical and led to absurd results, since the longer bridge might actually have a smaller total weight.

The next step, based to some extent on theory, was to specify a unit stress for the dead load different from that for live loads. For instance, in Cooper's 1902 specification, the permitted live load stresses were half as great as the dead load stresses. This rule was evidently based on the theoretical consideration that a load applied instantaneously has twice the effect of a slowly applied load. It always takes an appreciable time before the stress in a given member, due to a train passing over a bridge, reaches its maximum value. Hence, the

* Cons. Engr., New York City.

rule of halving the live load stress is not correct in theory, although undoubtedly safe in practice.

The next modification, and one that was widely used for some time, was to base the permitted stress on the maximum and minimum forces acting on the members at different times. This method was based on the formula of Professor W. Launhardt of the Royal Polytechnic School at Hanover, Germany. It was confessedly founded on the well-known series of experiments made by Professor Wöhler on the "fatigue" induced in iron bars under a large number of repeated loadings. Although the Wöhler tests were of great value, their application to bridge members, which act under entirely different conditions, was a doubtful step.

Even Professor Launhardt, with whom the speaker had occasion to discuss this matter while taking his course on bridge design, was quite ready to admit this. He was inclined to think that the more empirical methods of simply decreasing the permitted stress in long spans might be the better policy until further investigation should increase the knowledge of the subject. He somewhat whimsically called the exact determination of this question "music of the future".

In American practice, the Launhardt formula and the maximum minimum formula in its various forms, have been generally discarded for many years. They have been superseded by the expression for "impact" introduced by the late C. C. Schneider, Past-President Am. Soc. C. E., in his "Pencoyd" specification, and since then used in the specifications of the American Railway Engineering Association and other technical societies.

In these specifications, the effect of the live load is provided for in each member by an "impact" or "dynamic increment" which contains a term, *L*, equal to "the loaded length, producing the maximum strain in the member". This, of course, is proportional to the length of time during which the stress in the member gradually increases from zero to its maximum value.

The use of the term "impact" in the A. R. E. A. specification has been much criticized, of late, especially since recent deformation measurements on bridges under service conditions, give somewhat discordant results and seem to show that the effect of live loads has been exaggerated.

It should be remembered, however, that in bridge engineering, as in most other fields of construction, great importance must be assigned to practical experience with structures in actual use, and that, at all times, theoretical considerations must give way to the test of service.

It is not believed that it would be wise to build lighter bridges than those now in use, especially in view of the doubt as to the weight of future engine and train loads, until much more exact information has been obtained on such important questions as the strength of the newer alloy steels slowly coming into use, the strength of compression members, and the effect of live loads in bridge structures.

Henry B. Seaman,* M. Am. Soc. C. E.—It is interesting to learn as stated by Mr. Goldmark that Launhardt did not take his own formula seriously and was surprised that it should have been adopted so extensively in the United States. The subject was thoroughly reviewed by the speaker, from

* Cons. Engr., New York City.

the experiments to the final derivation of the formula, and the results presented to the Society in the form of a paper.* The conclusion reached was that the Launhardt formula was not a demonstration, and the tests themselves justified the inference that the effect of an indefinite number of applications of a load was about the same as that of the single application of a load at double this amount. This is the basis on which Cooper wrote his later specification making the allowable live load stresses equal one-half the allowable dead load stress. Similarly, it was seen that reversed stresses, indefinitely repeated, had the effect of the sum of these stresses if applied in one direction.

Methods of bridge design, since that time, have been entirely changed. It is recognized that a load, within the elastic limit, or yield point, may be applied an indefinite number of times without practical injury to the material from fatigue. Engineers, therefore, have sought to find the greatest stress effect of an applied train load, and, for this purpose, impact tests have been made. Whether those tests show the result of impact, vibration, etc., they show the greatest possible intensity from live load, and when the maximum intensity of live load is known, and the allowable stresses are kept well within the elastic limit, the assumptions provide for fatigue, and are safe.

When stresses up to 24 000 lb. per sq. in. are maintained, the limit of safety is nearly reached, considering that there are still some unknown secondary stresses. Therefore, the impact formula, so-called, should cover the most extreme conditions known. The tests which were shown, occur rarely, but they do occur, and it is just that contingency which should be met. This is the basis of present-day bridge design.

The fact that a bridge has stood the test of service does not necessarily mean that it has been economically designed or properly proportioned.

A bridge of heavy, wasteful design may show a good service record, yet another which is lighter in weight, but more rigid under traffic, may produce an equally good record in service.

Theodore Belzner,† Affiliate, Am. Soc. C. E. (by letter).‡—It seems that too much emphasis cannot be placed on Mr. Howard's views concerning column formulas,§ with reference to investigations on the initial internal strains which occur in structural members as the result of cooling at the time of fabrication, and which amount to many thousand pounds per square inch when converted into their corresponding stresses.

It is the writer's opinion that engineers should consider these internal strains in their relation to the subject of column formulas, and it would seem that such investigations and measurements as those made by Mr. Howard, not only are of importance to the Committee, but also to the Profession in general, and it is suggested that the Society encourage the publication of such papers, in order to arrive at satisfactory column formulas.

Warrick R. Edwards,|| M. Am. Soc. C. E. (by letter).¶—In one of the discussions of the Tentative Specifications for Steel Railway Bridges, the

* "The Launhardt Formula and Railroad Bridge Specifications," *Transactions*, Am. Soc. C. E., Vol. XLI (1899), p. 140.

† Insp. of Steel, Harlem River, Manhattan and Bronx Div., Dept. of Plant and Structures, New York City.

‡ Received by the Secretary, June 2d, 1922.

§ *Proceedings*, Am. Soc. C. E., April, 1922, pp. 877-878.

|| Baltimore, Md.

¶ Received by the Secretary, June 5th, 1922.

criticism is made that it is a specification of compromise. The thing most to be desired in a specification of this kind is that it shall meet with such general acceptance as to bring about a uniformity of practice and, at the same time, set as high a standard for practice as can reasonably be attained. A specification which cannot be readily adopted by the bridge engineers of the country as a whole will fail to accomplish any useful purpose, whatever its merits may be intrinsically. The great variety of views, on points both great and small, which has appeared in the discussions of this subject, both before the Society and the American Railway Engineering Association, is convincing evidence that only by mutual concessions can a common working ground be reached. It is difficult, therefore, to understand why "compromise" should be used as a term of reproach.

The writer is in hearty sympathy with those who believe that the Society would make a serious mistake in promulgating a specification which follows so closely the lines of the one recently adopted by the A. R. E. A. Such action could serve no good purpose and would result in confusion and annoyance. The Profession could be served best by a further compromise of the few differences through a joint action of the two Societies and the preparation of a single specification which would have both Societies back of it.

R. S. Chew,* M. Am. Soc. C. E. (by letter).†—The Committee has presented three column formulas, and it is assumed that it will not be amiss to present a fourth one for consideration. In a discussion of a paper by Mr. James E. Howard,‡ the writer called attention to the fact that there is a definite eccentricity in all columns due to imperfections in the member. Although it is probably true that this fact is appreciated, it has not been given sufficient prominence in various column theories or formulas. The writer does not believe that any theoretical treatment of value can be developed, except in so far as to indicate the various factors that must enter as empiric constants in the working formula.

In order to indicate the action in a column, one is compelled to consider an imperfect member the material of which is not homogeneous in either a horizontal or a vertical plane. Let Fig. 27 indicate a column the imperfections of which are such that the center of resistance is removed from the center of gravity of the section by a distance, e, at the plane of the application of the load and that this distance, e, varies throughout the length of the column.

Let the line, R, indicate this resistance axis. Any number of curves could be drawn to indicate a possible resistance axis, but the one shown indicates the worst condition.

From this line it may be noted:

(a) That all columns are crooked as regards resistance to axial compression.

(b) That the resistance axis does not lie in the plane of the principal axes, 1-1 or 2-2, except for circular sections.

* Cons. Engr., San Francisco, Calif.

† Received by the Secretary, June 14th, 1922.

‡ "Some Tests of Large Steel Columns", *Transactions*, Am. Soc. C. E., Vol. LXXIII (September, 1911), p. 469.

Although all theoretical treatments are based primarily on the bending of the column, which, as may be seen, is caused by a crooked axis, yet no one has recognized the condition (*b*), as the bending has been assumed to take place about Axis 1-1 or Axis 2-2.

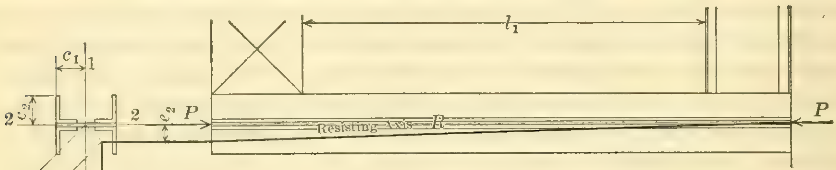
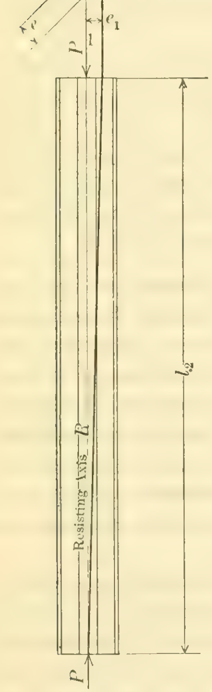

Fig. 27.

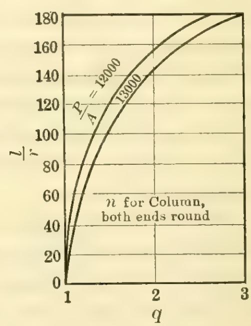

Fig. 28.

Let a theoretical formula be written for axial compression in which:

l = Length (unsupported);
P = Axial load;
A = Area of section;
S = Maximum unit stress on extreme fiber;
r_1 = Radius of gyration about Axis 1-1;
r_2 = " " " " " 2-2;
n_1 = Factor for end conditions about Axis 1-1;
n_2 = " " " " " " 2-2;
$\frac{\phi r}{t}$ = A factor proposed by Lilly.

The formula would appear as follows:

$$S = \frac{P}{A}\left[1 + \frac{\phi r}{t} + \sqrt{\frac{e^2_1 c^2_1}{r^4_1}\sec^2\left(\frac{n_1 l_1}{r_1}\sqrt{\frac{P}{A E}}\right) + \frac{e^2_2 c^2_2}{r^4_2}\sec^2\left(\frac{n_2 l_2}{r_2}\sqrt{\frac{P}{A E}}\right)}\right] \ldots\ldots (1)$$

Equation (1) is of no value except as a study from which, by substitution of empiric constants, a working formula may be derived.

Some of the conditions under which a column acts, as regards Factor n, are as follows:

(1) Pin-ended on Axis 1-1; semi-fixed on Axis 2-2; $l_1 < l_2$; no positive moment, that is, the load is assumed as axial.

(2) Same as Condition (1), except $l_1 = l_2$; no positive moment.

(3) Semi-fixed on both axes; $l_1 = l_2$; " " "

(4) " " " " "; $l_1 < l_2$ " " "

(5) " " " " "; $l_1 = l_2$; positive moment, M.

(6) " " " " "; $l_1 < l_2$ " " "

If r_1 is greater than r_2 and, assuming that the resistance axis does not lie in a plane, Axis 1-1 or Axis 2-2, then the resulting deformation is not that of bending alone, but is bending combined with twisting. Therefore, the combination of end conditions and lengths, l_1 and l_2, and the cross-section of the column must have an important bearing on the resulting stresses. Do either of the submitted formulas take any account of these conditions?

Working Formula.—If, by a series of tests, empiric values could be given to the factors, ϕ, e, and e_2, such that they would represent the average condition in commercial members carrying an axial load and having the various imperfections, Equation (1) would be valuable.

In regard to the factor, n, let:

$$\sec^2\left(\frac{n\,l}{r}\sqrt{\frac{P}{A E}}\right) = q \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

A series of curves may be drawn for assumed values of n and $\frac{P}{A}$ and for varying values, $\frac{l}{r}$, as shown in Fig. 28.

The formulas will then be:

$$S = \frac{P}{A}\left(1 + \frac{\phi r}{t} + \sqrt{\frac{e^2_1 c^2_1}{r^4_1} q_1 + \frac{e^2_2 c^2_2 q_2}{r^4_2}}\right) \ldots\ldots\ldots\ldots (3)$$

which, with curves and given values of ϕ, e, and e_2, furnishes a working formula. Equation (3) can be used in combination with the straight-line formula, that is, by determining a trial section by the following equation:

$$\frac{P}{A} = 15\ 000 - 50\,\frac{l}{r}$$

and checking for S in Equation (3).

The advantages of this formula are that it enables the designer to take care of positive moments and details, to check any damaged column, and to use his judgment between local and expert work for e.

H. M. MacKay,* M. Am. Soc. C. E. (by letter).†—Much of the discussion on these Tentative Specifications has centered around the proposed column formulas. The one great object of a column formula is to enable the designer to predict the strength of a column, and possibly the diversity of opinion expressed arises from the consciousness that no formula yet proposed is even approximately satisfactory as a means of predicting the strength of a given built-up steel column of ordinary length. Euler's formula is quite satisfactory within the range to which it is applicable, as one may demonstrate with no more elaborate apparatus than a straight lathe and a few weights. Rankine, as a reference to his works will show, had in mind solid or relatively thick-walled hollow struts of circular or rectangular section. Apparently, the only modern form which he visualized, was a rectangular box-section made up of plates and angles. Both these eminent elasticians, quite justifiably under the circumstances, made the slenderness ratio, $\frac{L}{R}$, the only variable in their well known formulas; and it is perhaps due to the weight of their authority that engineers, in so far as their ideas are expressed in specifications, have continued to regard the slenderness ratio as the only variable. One does not forget the many suggested formulas in which other factors are included, but none of these, as far as the writer is aware, has come into current use, or has, in a broad way, passed the test of satisfactorily predicting column strength.

The most comprehensive series of tests on steel columns of reasonable size is that of the Society's Special Committee on Steel Columns and Struts, reported in 1918.‡ Three variables were included in the specimens tested: Slenderness ratio $\left(\frac{L}{R}\right)$, form or make-up, and thickness of metal. Considering only those tests in the case of which the complete schedule was carried out, eight different forms were tested, each form with three different values of $\frac{L}{R}$, and two different thicknesses of metal. The heavier sections, on the average, had roughly about twice the sectional area of the lighter sections. Three individual columns were tested for each slenderness ratio, form, and weight, making 144 tests in all in the group considered. Thus, 48 members of each slenderness ratio were tested, 18 of each form, and 72 each of the lighter and heavier sections. The results of these tests may be tabulated as follows:

*Prof. of Civ. Eng., McGill Univ., Montreal, Que., Canada.

† Received by the Secretary, July 5th, 1922.

‡ *Transactions*, Am. Soc. C. E., Vol. LXXXIII (1919–20), p. 1583.

A.—In Respect of Slenderness Ratio:

$\frac{L}{R}$	Ultimate strength, in pounds per square inch.
50 (average of 48 tests)	33 150
85 (" " " ")	30 650
120 (" " " ")	28 100

B.—In Respect of Form or Make-up:

Form.	
5– 5*A* (average of 18 tests)	33 700
8– 8*A* (" " " ")	31 600
2– 2*A* (" " " ")	31 000
10–10*A* (" " " ")	30 400
4– 4*A* (" " " ")	30 400
3– 3*A* (" " " ")	30 200
1– 1*A* (" " " ")	29 100
6– 6*A* (" " " ")	28 600

C.—In Respect of Thickness of Metal:

Light (average of 72 tests)	32 200
Heavy (" " " ")	29 000

The most cursory comparison of these results shows that, as far as these tests are concerned, the influence of thickness of metal on ultimate strength is as great as that of a variation in $\frac{L}{R}$ from 50 to about 95, a range wide enough to include practically all the seriously loaded columns in a steel railway bridge; whereas, the influence of form on the ultimate strength, even neglecting Form 6–6*A* as unusual and undesirable, is nearly 45% greater than that of the stated variation in slenderness ratio. Had latticed columns been included in this series of tests the influence of form might well have been even more pronounced. Tests made for the Board of Engineers of the Quebec Bridge, in part by Mr. James E. Howard, and in part by the writer, indicated that members with solid transverse webs were 11 or 12% stronger, other things being equal, than those in which the ribs were connected by latticing only.

Although the Committee's tests bring out the influence of the thickness of metal in a way that no other tests do, any comprehensive group or groups of tests will indicate a large variation of strength due to form and detail, as compared with that due to a reasonable range in the value of $\frac{L}{R}$. When the strengths of a large number of columns are plotted against the slenderness ratio, the result is a broad belt of points through which a line can be drawn to suit any reasonable taste, or almost any formula. It is sometimes supposed that there is something erratic in the nature of column tests. For such a supposition, however, there seems to be little foundation. In the Committee's tests, the average extreme variation in each group of three members from the mean of the three, was 2.6 per cent. In the case of the Quebec Bridge tests referred to, the members are believed to have been among the largest, and certainly among the most complex, ever tested, the main section, in some cases, consisting of as many as thirty component parts. In this case, if in

any, erratic results might be anticipated. Yet, in fifteen pairs tested, the average variation of a member in each pair from the mean of the two was only 1.54 per cent. In fact, it is the writer's experience, derived from several scores of tests, that compression members are rather more consistent in their behavior than large riveted tension members.

It is, therefore, the writer's contention, supported as he believes by the whole body of available data, that the slenderness ratio, which in all formulas in general use is made the sole criterion for predicting the strength of columns of a given grade of material, is far from being the most important factor in the case of the great majority of heavily loaded columns. Approaching the question for the first time, and with an open mind, one would surely regard with astonishment the somewhat hair-splitting contentions in which individuals, and even committees, sometimes indulge, as to the precise function of $\frac{L}{R}$ to be used, whereas other and more important factors are ignored, except in respect to certain limiting clauses. Had equally unscientific methods been used in the calculation of tides, for instance, tide tables would have been based on the apparent diurnal motion of the moon. The consequent confusion of mariners, in Eastern waters, would hardly be greater than that of the designer who tried to correlate the strengths of various types of columns on the basis of their slenderness ratio.

It might be possible, as has been suggested, to devise different formulas for different types of column; but without much further investigation, agreement in this direction can hardly be expected. The form which it may be thought investigation should take, will depend largely on the view entertained as to column action. The writer's experience in testing and studying the stress distribution in built-up structural members leads him to the view that, for the purpose of investigation, a column can be advantageously regarded as an aggregation of strips, each tending to yield in its own way, but restrained by mutual interaction. In solid and in thick-walled hollow sections, such restraint is practically complete, and the column acts as a unit. In such cases, if uniform material of a known quality and free from internal stress can be assumed, it should be possible to express the strength satisfactorily as a factor of $\frac{L}{R}$. In the more usual types, there will be a variation according to form and detail. If this view is correct, two corollaries seem to follow:

1.—That no method of analysis is likely to be satisfactory, which assumes a linear variation of strain across the section, whatever relation between stress and strain may be assumed beyond the elastic limit, because such linear variation does not in general exist at the critical sections. Strain measurements show this to be true.

2.—That useful information regarding the laws of column action can be better obtained by an intensive study of a comparatively limited number of specimens, than by tests to destruction only, of a larger number. The latter seldom throw much light on the factors contributory to failure.

The possibilities of such intensive study are given on Fig. 29, on which is shown the stress distribution at certain sections of a column, consisting of four 2½ by 2½ by ¼-in. angles, 7 ft. 2 in. long, connected by tie-plates. The end-plates are ½ in. thick and project ½ in. beyond the angles so as to take the load which is transmitted to the angles through the connecting rivets. The intermediate tie-plates are ¼ in. thick. The stresses at the various sections, as determined by mirror extensometers over 2-in. gauge lengths, are plotted on the cross-section as a base plane, and the resulting solid is then shown in isometric projection. The distribution of stress can thus be seen at a glance. No extensometer readings were taken on contiguous surfaces of angles or

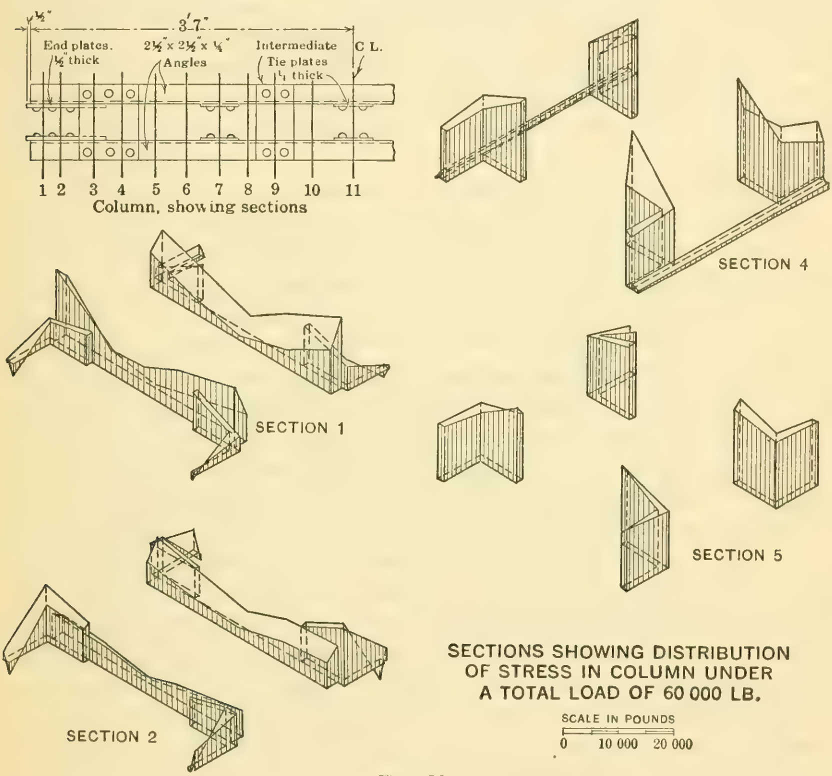

Fig. 29.

plates, so that, in such cases, the stress distribution is, to some extent, a matter of conjecture. However, in all cases, the stresses as plotted check the applied loads within 4 or 5 per cent. Section 1 is just within the first rivets nearest the ends of the angles. Most of the load remains in the plates, the angles taking only the amount transmitted by one rivet in each. At Section 2, the angles take an additional amount of load transmitted by a second rivet. The stress distribution remains far from uniform, certain fibers being in tension. At Section 5, where the angles take all the load, the stress distribution is fairly uniform, but this uniformity is disturbed again, where, as at Section 4, a tie-plate is encountered. Notwithstanding the greater sectional area at Sec-

tion 4, the maximum fiber stress in the angles is about 45% greater there than at Section 5. The stress distribution at all sections remained, to a remarkable extent, the same at all loads from 20 000 to 80 000 lb.

The stress survey, of which a few of the results are here shown, was made under the writer's direction by the late Lieut. H. G. S. Delepine. Such surveys are laborious; but the writer believes that only by the study of typical columns in some such manner can the Engineering Profession successfully take up the challenge which the present unsatisfactory knowledge of column action places squarely before it.

MEMOIRS OF DECEASED MEMBERS

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

SIR DOUGLAS FOX, Hon. M. Am. Soc. C. E.*

DIED NOVEMBER 13TH, 1921.

Sir Douglas Fox was born at Smethwick, Birmingham, England, on May 14th, 1840, and was the son of the late Sir Charles Fox and Lady Mary (Brookhouse) Fox. His father, Sir Charles Fox, was a pupil of and, subsequently, Assistant Engineer under Robert Stephenson. He designed and erected the First International Exhibition of 1851 in Hyde Park, for which he was knighted, and, subsequently, for many years practiced as a Civil Engineer in Westminster, London.

Sir Douglas Fox was educated at Cholmondeley School, Highgate, King's College School, and King's College, London, of which he was a Fellow.

In 1860, he and his brother, Sir Francis Fox, joined their father in his business, the firm practicing as Sir Charles Fox and Sons. On the death of Sir Charles Fox, the name of the firm was changed to Sir Douglas Fox and Partners, and the firm, now located in London, has since continued to act professionally, both at home and abroad, as Engineers in Chief and Consulting Engineers to many important undertakings, among the earliest of which was the construction of the approaches of the London, Chatham, and Dover and the London, Brighton, and South Coast Railways to London.

In conjunction with the late Sir James Brunlees, the firm was associated with the constructional designs of the Mersey Tunnel between Liverpool and Birkenhead, for which work Sir Douglas Fox was knighted.

The firm was professionally connected with the constructional designs of the Swing Bridge, over the River Dee, on the Chester and Connah's Quay Railway at Hawarden, Cheshire; the Liverpool, St. Helens, and South Lancashire Railway; the Liverpool, Southport, and Preston Railway; the Liverpool Overhead Electric Railway which was the first electrified railway in England; the Snowdon Mountain Railway; the Cardiff Railway, for the Marquis of Bute; the Neath, Pontardawe, and Brynamman Railway, and the Southern Extension (Rugby to London) including the Marylebone Terminus, of the Great Central Railway.

With the late W. R. Galbraith, the firm acted as Engineers in the construction of the Charing Cross, Euston, and Hampstead Tube Electric Railway, which was opened in 1907. The firm also acted as the Engineers during the construction of the Great Northern and City Tube Electric Railway, from Finsbury Park to Moorgate Street, which was opened in 1904, and its members are Consulting Engineers to the Channel Tunnel Company, in connection with the proposal to construct a tunnel between England and France.

* Memoir prepared by Sir Douglas Fox and Partners, London, England.

During the World War, the firm was associated with the design and construction of docks and slipways for Lord Furness, at Middlesbrough, the Explosives Factory for the Admiralty at Holton Heath, Dorset, and the Explosives Factory for Nobel's Explosives Company at Pembrey, South Wales.

Sir Douglas Fox and Partners are engaged also as Engineers for important hydro-electric works in North Wales, for the Aluminum Corporation, Limited, and Joint Consulting Engineers, with Messrs. Livesey, Son and Henderson, to the Central Argentine Railway Company. With Sir Charles Metcalfe, the firm is acting as Joint Consulting Engineers to the Shiré Highlands (Nyasaland) Railway Company, the Rhodesia, Mashonaland, and Beira Railway Company (Cape to Cairo), the Benguella Railway Company, the Trans-Zambesia Railway Company, and to the British South Africa Chartered Company.

With the late Sir George Bruce and Mr. Robert White, the firm of Sir Douglas Fox and Partners was for many years Joint Consulting Engineers to the South Indian Railway Company, and is acting as Consulting Engineers to the Southern San Paulo Railway Company and the Dorada (United States of Colombia) Railway Company. The firm was responsible for the design of the steel bridge over the Zambesi River, at the Victoria Falls, in Rhodesia.

Sir Douglas Fox was constantly engaged as an expert engineering witness in the Parliamentary Committee Rooms at Westminster, and in connection with the promotion and opposition to bills for the construction of railways, harbors, etc., and the London tube railways.

He was interested in many companies. He served as Chairman of the British Griffin Chilled Iron and Steel Company, Limited, Barrow-in-Furness, the Improved Industrial Dwellings Company, Limited, Northfleet Coal and Ballast Company, Limited, Venezuela Telephone and Electrical Appliances Company, Limited, and The Thurrock Chalk and Whiting Company, Limited. He was a Director of the British South African Explosives Company, Limited, City of Las Palmas Water Company, Limited, Haematite Ore Concentrates, Limited, Pondicheri Railway Company, Limited, South Indian Railway Company, Limited, and United Electric Tramways Company of Caracas, Limited.

In 1921, he was presented with a testimonial by the Shareholders of the Northfleet Coal and Ballast Company, Limited, in recognition of his fifty years of service as Chairman, during which period he never missed an Annual General Meeting.

He was President of the Institution of Civil Engineers from 1899 to 1900 and, for many years, was an active member of its Engineering Standardization Committee. He was also a member of the Institution of Mining Engineers and the Institution of Electrical Engineers.

On May 26th, 1863, he was married to Miss Mary Wright, daughter of the late Francis Beresford Wright, Esq., of Osmaston Manor, Derby. He is survived by five children, a son, Francis Douglas Fox, and four daughters. He was deeply interested in all Christian and philanthropic work.

Sir Douglas Fox was elected a Corresponding Member of the American Society of Civil Engineers on June 7th, 1871, and an Honorary Member on March 5th, 1901.

GEORGE BARKER BURBANK, M. Am. Soc. C. E.*

DIED FEBRUARY 29TH, 1920.

George Barker Burbank was born in Taylorsville, Ky., on March 16th, 1844. His parents were of New England stock; his father, Moses Burbank was a native of Salem, Mass., and a graduate of Waterville College (now Colby College), Maine, and his mother, Nancy Baker, came from Lowell, Mass.

At the outbreak of the Civil War, George Barker Burbank, then a lad of sixteen, was living in Ludlow, Vt. Misrepresenting his age, he enlisted in Company I, Second Vermont Infantry. He was in all the battles of the Army of the Potomac from the first battle of Bull Run to that of the Wilderness. For exemplary conduct during the Battle of Fredericksburg, he was mentioned in orders and granted a furlough home. He was seriously wounded while serving as a Sergeant, at the Battle of the Wilderness, and his discharge followed his recovery. Mr. Burbank retained his intense patriotism throughout his life, and it was a keen satisfaction to him that his son, Clinton Montrose Burbank, Lieut., 2d Cavalry, U. S. A., served, with honorable mention and wounds, during the World War, half a century after his own military service was past.

From 1866 to 1884, Mr. Burbank practised his profession, chiefly railroad building, in the South and West. In 1885, he accepted an appointment as Assistant Engineer for the New York Aqueduct Commission, and, thereafter, with a few brief interludes, he resided in or near New York City, making his home for many years in White Plains, N. Y.

The following is a brief list of the more important engineering works with which Mr. Burbank was actively identified:

From 1867 to 1869, he was with the Louisville, Cincinnati and Lexington Railroad in Kentucky, filling all grades from Rodman to Engineer of Repairs, and from 1869 to 1870, he served as Division Engineer and Assistant to the Chief Engineer of the Cincinnati Southern Railway in Kentucky.

From 1870 to 1873, he was engaged as Division Engineer of the Wisconsin Central Railway, and from 1873 to 1874, as Resident Engineer of the Chesapeake and Ohio Railway.

From 1874 to 1875, he served as Division Engineer of the Cincinnati Southern Railway in Tennessee.

From 1876 to 1880, he was employed as Engineer, with the Eouhardt and Aurora Mining Company, Limited, in Nevada, and from 1880 to 1884, as Division Engineer and Deputy Chief Engineer, with the Rio Grande Western Construction Company.

Mr. Burbank was connected with the New York Aqueduct Commission, from 1885 to 1890, as Assistant Engineer and Engineer of Dam Construction, and from 1890 to 1894, he was employed by the Cataract Construction Company, of Niagara Falls, N. Y., as Resident Consulting and Chief Engineer. He was also engaged by the National Contracting Company, of New York City, from 1900 to 1903, as Consulting Engineer, and served the York Haven Power and Paper Company in a like capacity from 1903 to 1906. From 1911

* Memoir prepared by William Mayo Venable, M. Am. Soc. C. E.

to 1913, he was connected with the United Comstock Pumping Association and Siskiyon Mines Company, in Nevada and California, as General Manager.

In his general practice as Consulting Engineer, Mr. Burbank also investigated and reported confidentially on many other projects, with the execution of which he was not identified. This work took him to Porto Rico and Alaska, as well as to various parts of the United States.

Mr. Burbank continued in the active practice of his profession almost until the day of his death. The spirit of adventure which influenced the boy of sixteen to enlist, and a certain natural hardiness which made a pleasure of roughing it, characterized him throughout his active career. In the winter of 1906-07, at the age of sixty-two, he made a trip of 800 miles through the wilds of Alaska by dog team.

He is survived by his wife, a son, Clinton Montrose Burbank, and a daughter, Marjorie Church Burbank.

He was a Mason, and, at one time, Commander of Ludlow (Vt.) Post, G. A. R.

Mr. Burbank was elected a Member of the American Society of Civil Engineers on July 4th, 1888.

HOMER HAMLIN, M. Am. Soc. C. E.*

DIED MAY 14TH, 1920.

Homer Hamlin was born on August 27th, 1864, at Pine Island, Minn. He was educated in the public schools of Minnesota, and, later, was a teacher in the State.

In 1886, Mr. Hamlin went to San Diego, Calif., where he was employed for several years by the City Engineer. After leaving the City Engineer's office, he was engaged in private practice until 1894, when he left San Diego to make his home in Los Angeles.

From 1894 to 1901, he served in the offices of the County Surveyor of Los Angeles County and the City Engineer of Los Angeles. In January, 1899, he was appointed Chief Deputy of the Field Force in the latter office, a position which he filled for nearly three years. He left this position in 1901, to become an Engineer in the United States Reclamation Service, and while thus employed, he served as Project Engineer for the Yuma Project, which included the construction of the well known Laguna Dam across the Colorado River. He also made a study of the geological features of the Salinas Valley, in connection with a report which he prepared on the water resources of that section of California.

In August, 1906, Mr. Hamlin was appointed City Engineer of Los Angeles, and filled this position until July, 1917. He was also a member of the Advisory Board for the construction of the Los Angeles Aqueduct. During this period, a number of engineering works of notable character were constructed under his supervision. Particular mention should be made of the

* Memoir prepared by a Committee of the Los Angeles Section: J. B. Lippincott, M. Am. Soc. C. E., and the late Edgar True Wheeler, M. Am. Soc. C. E., with additional information supplied by W. T. Knowlton, M. Am. Soc. C. E.

completion—under methods proposed by him and executed by City forces—of the Los Angeles Outfall Sewer. This work, which comprised a series of tunnels in water-bearing formation, was abandoned by the contractors, who declared that its completion was impossible. Other work done under his supervision included that at Los Angeles Harbor, the construction of the Hill Street Tunnel, the adoption, on his advice, of the Trilby rail, etc.

After leaving the employ of the City of Los Angeles, Mr. Hamlin engaged in private practice, devoting a large part of his time to work, as Consulting Engineer, for the Reclamation Service in Arizona, California, and Wyoming.

In connection with the Salt River Irrigation Project, and as a delegate representing the Association of Water Users of the Salt River Valley, he was attending a hearing before the Secretary of the Interior at Washington, D. C., when, on May 14th, 1920, he was seized with a cerebral hemorrhage and died very suddenly while alone in his room at the Willard Hotel. He is survived by his widow and two children.

Mr. Hamlin was a distinguished member of the Engineering Profession in the Southwest, and a brilliant example of the type of man who is a real public benefactor. Modest, hardworking, conservative, and sound in judgment, he has assisted materially in making the region of his adoption a place where a much greater number of people can reside happily. There is no nobler work that a man can do than to convert the desert into gardens, to improve the sanitation of cities, and add to the commercial development of the country by the construction of harbors, as Mr. Hamlin did. With all this, he was of a modest nature, shunning publicity, and avoiding ostentation over his accomplishments. His death is not only regretted by his friends, but is a distinct loss to the Reclamation Service and to the community in which he made his home.

Although Mr. Hamlin was largely a self-educated engineer, he was a natural student. In addition to his other technical studies, he specialized extensively in geological research. This was his recreation. His report on the "Water Resources of the Salinas Valley", written for the United States Geological Survey in 1901-02, was one of his most important geological studies. He was also identified with the early development of some of the oilfields of Southern California. A few months prior to his death, he had made a trip down the Colorado River from the mouth of the Virgin to Yuma, Ariz. This expedition was devoted particularly to the study of the possibilities of the great storage enterprise at the lower end of the Grand Canyon, at a point known as Boulder Canyon.

Mr. Hamlin was a member of the American Association of Engineers and of the Seismological Society of America. He was also a member of the Westlake Methodist Episcopal Church of Los Angeles.

The following resolution on his death was adopted by the Los Angeles Section of the Society of which he was a member:

"*Whereas,* It has pleased the Almighty to remove from our midst our fellow member, Homer Hamlin, this Society desires to express its sympathy to his bereaved widow and children, and to heartily condole with them in their poignant grief.

"His death will prove a distinct loss to his town, the State and the Nation, to whose service he has been, throughout his whole professional life, assiduously devoted.

"We desire to express our deep appreciation of his upright and manly character as an engineer and a citizen. As an engineer he was thorough, careful and reliable, honorable and conscientious, and not to be swerved from the straight path of rectitude by either fear or favor. As a citizen he was a model husband, father and neighbor, and his pure and moral life set a noble example for the young of all classes, and particularly for the members of his chosen profession.

"*Resolved,* That this resolution be spread upon the minutes of this Society, and a copy be sent to Mrs. Hamlin and family, with our deepest sympathy and condolence in their affliction.

"'His life was gentle, and the elements so mixed in him that Nature might stand up and say to all the world, this was a man'."

Mr. Hamlin was elected a Member of the American Society of Civil Engineers on May 4th, 1904.

EMIL EDWARD KUERSTEINER, M. Am. Soc. C. E.*

Died March 10th, 1913.

Emil Edward Kuersteiner was born on March 26th, 1857, at New Orleans, La., where he resided until his parents removed to Cincinnati, Ohio, in 1878. He was graduated from the Woodward High School at Cincinnati in 1874, afterward going to Europe to obtain his engineering education. He was graduated from the Polytechnic School of Switzerland, at Zurich, in 1879, with the degree of C. E., and remained at his Alma Mater as Assistant to Professor Culman, Professor of Graphical Statics and Civil Engineering, for a year, returning to the United States in the Fall of 1880.

From 1881 to 1885, Mr. Kuersteiner was employed as Draftsman by the Cincinnati Southern Railway and the New Orleans and Northeastern Railway, under the late L. G. F. Bouscaren, M. Am. Soc. C. E.; and from 1885 to 1888, he served as Draftsman and Computer with the Louisville Bridge and Iron Company of Louisville, Ky., with which Company he remained, in charge of the Drawing Room, until 1896. In 1896, he removed to Johnstown, Pa., and took charge of the Drawing Room of the Johnstown Company; but in 1898, he returned to Louisville, and was engaged in the Bridge Department of the Louisville and Nashville Railroad Company, "on trial for a period of thirty days."

W. H. Courtenay, M. Am. Soc. C. E., Chief Engineer of the Louisville and Nashville Railroad, writes of Mr. Kuersteiner, as follows:

"He acted in the capacity of Assistant Bridge Engineer until November, 1906, when he became Bridge Engineer, and served in that capacity until a short time before his death. His work covered a long period of reconstruction of bridges for heavier loads on operated lines, and the construction of numerous structures on new lines. Until 1904, he and the Bridge Engineer practically handled all the bridgework, preparing plans for the masonry and checking the designs for the steelwork. All this work was very exacting, but he performed

* Memoir prepared by William Mayo Venable, M. Am. Soc. C. E.

his work with apparent ease, as he was an excellent mathematician, an able and accomplished engineer, and a very accurate and tireless worker. He had a host of friends, all of whom knew him as Mr. 'K'. He was a man to whom young men went for advice and help. His opinions in matters pertaining to his profession and community interests were often sought by others and were always found to be exceedingly helpful and valuable, as he was a cultured, educated man of clear judgment."

Mr. Kuersteiner was a man who sought usefulness rather than preferment. He always helped others when it was within his power, without first thinking of his own interests, and he was intensely loyal to his work, his friends, and his ideals.

He was married in Louisville, Ky., and is survived by his wife, four sons, and a daughter.

Mr. Kuersteiner was elected a Member of the American Society of Civil Engineers on December 1st, 1897.

FRANK CHITTENDEN OSBORN, M. Am. Soc. C. E.*

DIED JANUARY 31ST, 1922.

Frank Chittenden Osborn, the son of Reuben Howard and Livonia (Chittenden) Osborn, was born at Greenland, Mich., on December 18th, 1857. His early education was acquired at Calumet, Mich., and he received his technical education at Rensselaer Polytechnic Institute, Troy, N. Y., from which he was graduated in Civil Engineering in 1880.

After his graduation, Mr. Osborn entered the employ of the Louisville Bridge and Iron Company as Assistant Engineer, which position he held until 1885, when he became Principal Assistant Engineer of the Keystone Bridge Company. In 1887, he joined the firm of G. W. G. Ferris and Company, Inspectors and Designers of Structural Steel Work, with headquarters in Pittsburgh, Pa.

In 1889, he accepted the position of Chief Engineer of the King Bridge Company, of Cleveland, Ohio, but resigned in 1892 to open an office for the private practice of engineering. This business developed to such an extent that, by 1900, it was incorporated as The Osborn Engineering Company, and became one of the best known firms of the Middle West. Mr. Osborn was connected with the Company as Director at the time of his sudden death on January 31st, 1922, at his home in Cleveland, Ohio.

Mr. Osborn's professional life was devoted to the fabrication of structural steel in bridges and buildings. His Company designed a large number of steel and reinforced concrete bridges for cities and corporations throughout the United States, including those for steam and electric railways and grade eliminations. These bridges included two-hinge and three-hinge arch types, spandrel-braced, and plate-girder construction, and among them was the Y-bridge, a three-arm structure over the Licking and Muskingum Rivers, at Zanesville, Ohio, at that time the largest reinforced concrete bridge in the United States.

Mr. Osborn's keen interest in good designs for bridges led him to make

* Memoir prepared by Willard Beahan, M. Am. Soc. C. E.

a collection of views of many of the best and most beautiful of such structures throughout the world. He was a pioneer in concrete and reinforced concrete construction, as has been shown, and his studies extended to the design and construction of nine Portland cement plants, with a producing capacity of 17 000 bbl. of cement per day.

In 1908, Mr. Osborn was appointed a member of the Cuyahoga County Building Commission, which Commission had charge of the erection of the new Court House in Cleveland. This is one of the most notable buildings in that part of the State and cost $5 000 000. He was also a Director of the Lake Shore Banking and Trust (Savings) Company, in Cleveland.

He was the author of a valuable treatise entitled "Tables of Moments of Inertia and Squares of Radii of Gyration", which was published in 1886. He also devised a code of conventional signs for bridge riveting, which is now in general use, and proposed to bridge engineers and to manufacturers a standard size of sheet, of 24 by 36 in., for bridge drawings, which is also in general use.

He was one of the early (1889) members of the Cleveland Engineering Society, having served as its Secretary in 1897, and its President in 1898. He was a consistent contributor to its publications and presented many books to its Library, served on its important committees, and was most active in its affairs to the time of his death. He was also a member of the American Railway Engineering Association, the American Society for Testing Materials, and the Institution of Civil Engineers of Great Britain.

Mr. Osborn was a member of the University Club and of the Athletic Club of Cleveland, and was Chairman of the Advisory Board of the Cleveland Technical High Schools. He served as Vice-President of the Alumni Association of Rensselaer Polytechnic Institute in 1910, and was earnest in his relations to his Alma Mater, lecturing to the Senior Class, and, in 1910, he delivered the address before the Graduating Class. He was a member of the Sigma Xi Society, an honor society of technical graduates chosen by the Alumni of his Alma Mater.

He was very active in civic and patriotic affairs, his interest having been prompted by his lineage. He was a member of the Society of Colonial Wars, the Sons of the American Revolution, the New England Society of Cleveland, the Western Reserve, the Western Reserve Historical Society, the Navy League, the Aerial League of America, and the National Geographic Society.

Mr. Osborn was also a member of the Masonic Club, and a very active and earnest Mason, his membership in Masonic Fraternities dating from 1891. He was a member of Tyrian Lodge, Cleveland Chapter, Cleveland Council, Holyrood Commandery, Lake Erie Consistory, and Al Koran Temple.

As an engineer, Mr. Osborn was a pioneer in the best class of bridge and structural design, and he has left much excellent construction showing originality and early study. As a citizen, he gave unselfishly of his best efforts and much time and strength to those things which insure the safety, health, and happiness, of his fellows.

As a man, he was most kindly to the younger men of his profession, and gladly welcomed the engineer who was a stranger to his city. His was a service

rendered beyond remuneration, and he made the interests of his clients and his neighbors his own.

On October 27th, 1880, Mr. Osborn was married at Calumet, Mich., to Annie, daughter of Stephen and Amelia Hodgess Paull. His wife and their son, Kenneth Howard Osborn, M. Am. Soc. C. E., survive him.

Mr. Osborn was elected a Member of the American Society of Civil Engineers on October 3d, 1888. He served as a Director in 1901-03, and was a member of the Special Committee on Steel Columns from 1909 to 1916. He had been a member of the Cleveland Section from its organization, and had served on its Committee on the Cuyahoga Valley Development.

LINGAN STROTHER RANDOLPH, M. Am. Soc. C. E.*

Died March 7th, 1922.

Lingan Strother Randolph was born on May 13th, 1859, at Martinsburg, Va. He was the son of James L. Randolph and Emily Strother Randolph and was directly descended from William Randolph who settled at Turkey Island, Virginia, soon after the settlement at Jamestown, in 1607. Several members of the family distinguished themselves in the Engineering Profession. His father, the late James L. Randolph, M. Am. Soc. C. E., was Chief Engineer of the Baltimore and Ohio Railroad for many years, and his brother, Beverly Randolph, was Chief Engineer of the Consolidation Coal Company.

Lingan Strother Randolph received his early education in private schools and at the Virginia Military Institute. He also served an apprenticeship at the shops of the Baltimore and Ohio Railroad at Grafton and Mt. Clare, Md. In 1881, he entered the Junior Class at the Stevens Institute of Technology and was graduated with the degree of M. E. in 1883. At the Forty-ninth Annual Commencement, on June 21st, 1921, he received the Honorary Degree of Doctor of Engineering from the Institute.

From 1883 to 1885, Mr. Randolph was employed by the Erie Railway at Susquehanna, Pa., as Engineer of Tests. He held the position of Superintendent of Motive Power of the Florida Railway and Navigation Company from 1885 to 1887, at which time he left Florida to become Superintendent of Motive Power of the Cumberland and Pennsylvania Railway, which position he retained until 1890. He was employed as Engineer of Tests on the Baltimore and Ohio Railroad from 1890 to 1892, and as Electrical Engineer by the Baltimore Electric Refining Company from 1892 to 1893.

As Professor of Mechanical Engineering and, later, as Dean of the Engineering Department, he was a member of the Faculty of the Virginia Polytechnic Institute from 1893 to 1918. It was during his twenty-five years at the Virginia Polytechnic Institute that Professor Randolph rendered his greatest service to the Engineering Profession. Those trained under him not only received a thorough knowledge of the profession, but were given a

* Memoir prepared by H. A Gillis, Esq., Washington, D. C.

practical working knowledge of the problems that would be met in later life. The students were also trained in the highest ethics of the profession.

Of his work at the Virginia Polytechnic Institute, Dean Theodore P. Campbell, writes:

"Professor L. S. Randolph succeeded, as Professor of Engineering, the late James H. Fitts, who was unfortunately killed in a railroad accident on his way to the Chicago Exposition. If my recollection serves me aright, Professor Randolph was suggested to the President of the Institution by the President of the Baltimore and Ohio Railroad.

"He entered on his duties as Professor of Engineering in September, 1893. The Engineering Department was subsequently developed and divided into Mechanical, Electrical, and Civil Engineering—Mining Engineering being introduced many years later. When the above division took place, Professor Randolph was made head of the Mechanical Engineering Department and had charge of the college shops and of the college repair work. He remained head of the Mechanical Engineering Department until his resignation was tendered in 1918.

"During the latter part of President Barringer's administration, Professor Randolph was made Dean of the whole Engineering Department. This office he filled until his connection with the institution was terminated by his resignation.

"Professor Randolph brought to the institution a wide knowledge of men in the professions and in the business world. He was instrumental in making this institution known to the various engineering and business activities. It was he who brought it into actual connection with the engineering societies. He also possessed, in a large degree, and emphasized with the students, the human element in engineering. The fact that Professor Randolph was highly esteemed and valued by these various men and organizations was brought to my attention as Dean of the institution. As a professor, he was very popular with his classes, and I have often noticed, as have others of his associates, that, when the old men returned here, it was almost invariably Professor Randolph they asked for first, showing the affection and esteem in which they held him.

"Professor Randolph's activities were, however, in no sense, limited to the classroom. He was largely responsible for putting the Y. M. C. A. on a secure footing at the V. P. I. and for maintaining it there. He was generous almost to a fault and extremely liberal in his contributions to the Y. M. C. A.

"He was an Elder in the Presbyterian Church in this town, in which he retained his membership until his death. He was very much interested in all the interests and activities of the church and for a long period of years taught a Bible Class in the Presbyterian Sunday School and also conducted a Normal Class in the Y. M. C. A.

"To him also, more than to any other one man, and almost entirely to him, I may say, was due the fact that what is now a branch of the Norfolk and Western Railroad connecting Blacksburg with the main line of the Norfolk and Western at Christiansburg, was built and operated.

"As a man, he was what may be termed a 'big man'—a man of big heart and big ideas. I was intimately associated with him for 24 or 25 years and can truly say that I never saw anything in Professor Randolph's actions that smacked the least of pettiness. He was a faithful friend, a genial companion, an earnest Christian, a useful citizen, and his influence in any community in which he lived could not but be helpful and elevating."

Professor Randolph found time from his duties at the Virginia Polytechnic Institute to perform a great deal of important consulting work. He also wrote a number of papers and discussions for the Society and for the other

engineering societies of which he was a member, among which were the American Society of Mechanical Engineers, the International Association for Testing Materials, the American Institute of Electrical Engineers, and the Tau Beta Pi Fraternity.

During the World War, he served in the Research Section of the U. S. Shipping Board, Emergency Fleet Corporation, and the latter part of his life was spent in looking after his special interests, among which was the Brush Mountain Coal Company of which he was President.

He was married on October 15th, 1890, at Cumberland, Md., to Fanny Robbins, who, with three sons and one daughter, survives him.

Professor Randolph was elected a Member of the American Society of Civil Engineers on January 2d, 1890.

SAMUEL CLARENCE THOMPSON, M. Am. Soc. C. E.*

Died February 28th, 1920.

Samuel Clarence Thompson, the son of Samuel Newman Thompson and Mary Ann (Washburn) Thompson, was born in Roxbury, Mass., on April 4th, 1851. The family moved from Roxbury to Southboro, Mass., while Mr. Thompson was in his early boyhood. He won a scholarship in the Massachusetts Agricultural College and was graduated therefrom in 1872.

In 1875, Mr. Thompson was engaged as an Assistant Engineer on the new Water Supply Commission of the City of Boston, and in 1879 was appointed as Acting Chief Engineer on the construction of the South Florida Railroad. Later, in 1881, he was made Assistant City Engineer of Lowell, Mass., and, in this capacity, had charge of the laying of the large supply main from the high-service reservoir in Centralville, under the Merrimac River, to Belvedere. Subsequently, he was in charge of rebuilding the bridge across the Merrimac River.

Mr. Thompson came to New York City in 1883 and entered the service of the municipality in the Department of Parks, in the Borough of the Bronx, which, at that time, was known as the 23d and 24th Wards. He continued his connection with the City of New York in the Department of Highways, through its changes of name and jurisdiction, until his death on February 28th, 1920.

Mr. Thompson was in the service of the city for 37 years and, until his last illness, lost only 3 days from his work during that time. He was in charge of the Bureau of Highways in the Office of the Borough President of the Bronx for many years, and there are numerous monuments in the Borough to his ability and energy as an Engineer. He was also in charge of the regulating, grading, and paving of most of the streets in the West Bronx, of the construction of the Grand Boulevard and Concourse, and of all its connecting transverse roads.

* Memoir prepared by Josiah H. Fitch, M. Am. Soc. C. E.

On May 5th, 1875, he was married to Miss Alice Louise Fairchild of Natick, Mass., who, with a daughter, Mrs. Elsie Thompson Shepard, survives him.

Mr. Thompson was a Charter Member and a Past-President of the Municipal Engineers of the City of New York. He was also a member of the National Geographic Society and the League of American Sportsmen, a Knight of Honor, a member of the Royal Arcanum and of the Loyal Association of the Royal Arcanum, of Roome Lodge No. 746, F. and A. M., Chancellor of the Supreme Court of the Phi Sigma Kappa, and a member of the Phi Kappa Phi.

His loss was deeply felt by the Engineering Corps in the Office of the President of the Borough of the Bronx and by all his associates and friends.

Mr. Thompson was elected a Member of the American Society of Civil Engineers on February 6th, 1889, and served as a Director from 1909 to 1911.

ROBERT ATTWELL WAY, M. Am. Soc. C. E.*

DIED APRIL 6TH, 1901.

Robert Attwell Way was born on January 29th, 1854. In 1871, he entered the Royal Indian Engineering College at Cooper's Hill, Egham, Surrey, England, from which he was appointed as Assistant Engineer in the Public Works Department of the Government of India.

He proceeded to India in 1873 and was assigned to the Rajputana Malwa Railway. In 1879, he was transferred, as Executive Engineer, to Kathiawar and was placed in charge of the survey and construction of the Gondal Branch of the Bhavnagar Gondal Railway, for which he received the recognition of the Government of Bombay.

In 1887, Mr. Way's services were lent to the Bengal Nagpur Railway as Superintending Engineer, and, in 1889, he was appointed Engineer-in-Chief of the construction of the Delhi-Umballa-Kalka Railway which he completed in 1892. He then returned to the service of the Government and for the next few years was employed on surveys for lines to connect Assam and Burma.

In April, 1896, he was selected by the Board of Directors of the Assam-Bengal Railway as their Agent and Chief Engineer in succession to Mr. John Walker Buyers. In April, 1901, after five years service with the Company, he died in Chittagong, India, after a short illness.

The difficulties and privations of his work in India sowed the seeds of disease which killed Mr. Way in the prime of life. He was kindly and cheerful in disposition and his ability as an Engineer was considerable. In fact, he was regarded as one of the coming men in connection with railway development in India.

In acknowledging the news of his death, the Board of Directors of the Assam-Bengal Railway, wrote as follows:

"Mr. Way was appointed to the Agency and Chief Engineership in April, 1896, and was thus connected with the railway for a period of five critical

* Memoir prepared by Evelyn Brook-Fox, Assoc. M. Am. Soc. C. E.

years, covering the completion of the Chittagong Section and its organization on an open-line basis, as well as the execution of the greater part of the construction work on the Northern Sections of the line, work of an exceptionally arduous character, and sufficient by itself to tax to the full the skill and energy of those responsible for it.

"During this period, Mr. Way not only sustained both as an Engineer and a Manager the high reputation with which he entered the service of the Company but, in the opinion of the Board, greatly added to it.

"The Directors feel that they have lost an Officer who, by his ability and devotion to his work, commanded their entire confidence, and they deplore his death as a great misfortune to the Company."

Mr. Way was elected a Member of the American Society of Civil Engineers on June 7th, 1893.

EDGAR TRUE WHEELER, M. Am. Soc. C. E.*

Died March 2d, 1922.

Edgar True Wheeler was born in San Francisco, Calif., on November 3d, 1870. He was the son of Samuel H. Wheeler, a prominent San Francisco engineer who originated the first cable-car system in that city. Edgar True Wheeler received his first schooling in San Francisco and, later, moved with his parents to the vicinity of Westminster, Calif. Subsequently, he moved to San Diego, Calif., where he became actively engaged in the Engineering Profession, having been attached to the City Engineer's Office from 1886 to 1889.

In 1889 and 1890, he was engaged in location work on the Cuyamaca Railroad in San Diego County, which is now the San Diego and Arizona Railroad, when he was appointed to make the preliminary survey for the Bear Valley Irrigation Company and the Arrowhead Reservoir Company.

In 1891, Mr. Wheeler joined the Engineering Department of the Seattle, Lake Shore and Eastern Railroad and was engaged on bridge construction. The lure of Southern California made itself felt, however, and, in 1892, he was again appointed Engineer for the Arrowhead Reservoir Company, in charge of the topographical and irrigation surveys.

In 1893, he entered the Engineering Department of the City of Los Angeles, and was Assistant in charge of the Outfall Sewer. On the completion of this work, he became associated with James T. Taylor, M. Am. Soc. C. E., in general engineering, until 1894, when he re-entered the City Engineering Department of Los Angeles. He remained with this Department until 1896, when he became Assistant Engineer of Construction for the Pasadena and Pacific Electric Railway.

From 1896 to 1900, Mr. Wheeler was Assistant Engineer of Bridges and Tunnels, which the City of Los Angeles was building at that time. During the construction of the Third Street Tunnel, he met with an accident, and, while recuperating, left for Mexico and joined the Engineering Staff of the Mexican-Central Railroad. In 1901, with his injury still troubling him, he went to

* Memoir prepared by C. W. Resman, Esq., Los Angeles, Calif.

Michigan, where he became Principal Assistant in charge of the construction of all coal docks and bridges on the Copper Range Railroad. The cold weather again sent him to Southern California, where he joined the Engineering Staff of the Pacific Electric Railway, in charge of all bridge construction and designing. During 1905 and 1906 he was engaged in private practice, but still had charge of all bridge designs for the Pacific Electric Railway.

Mr. Wheeler then entered the firm of the Mercereau Bridge and Construction Company, General Contractors, specializing in bridges, wharves, and concrete structures, as Vice-President and Engineer, in charge of all estimates, designs, and construction.

In 1911, he organized the Edgar T. Wheeler Company, a corporation engaged in general engineering and contracting business, of which he was President.

During the World War, he left the corporation as an active member, and entered the Government service as Superintendent of Construction at Rockwell Aviation Field. Later, he entered the Army Service, as a Captain of Engineers, and was stationed with the 125th Engineers.

In April, 1920, Mr. Wheeler was associated with the late Homer Hamlin, M. Am. Soc. C. E., former City Engineer of Los Angeles, with whom he was very intimate, in making a survey of the Colorado River, for possible dam sites and also to obtain additional data on the Boulder Canyon Project. This trip was made in rowboats, and was spoken of by Mr. Wheeler, as being the best vacation he had ever had.

In January, 1921, he again revived the charter of the Edgar T. Wheeler Company which had been inactive during the war and managed it until his death. On February 25th, 1922, he was taken ill with influenza, which, a few days later, developed into pneumonia, and caused his death on March 2d, 1922, after an illness of five days.

Mr. Wheeler had made extensive plans for the future and was very optimistic regarding the growth of Los Angeles, as well as the prosperity of the coming year; he was a great booster, having been a pioneer of Southern California. Due to his splendid personality, he had a host of friends and acquaintances. As an engineer, he had developed wonderful judgment, and in his death the Engineering Profession has lost a valuable member.

Mr. Wheeler was a member of the American Society of Military Engineers, and of the Los Angeles Section of the Society which passed the following resolution on his death:

"*Whereas,* In His infinite wisdom it has pleased the Almighty Providence to take from us our beloved fellow-member Edgar True Wheeler, and,

"*Whereas,* The Los Angeles Section, American Society of Civil Engineers, desires to express its sympathy to his bereaved widow and children and condole with them in their grief, and

"*Whereas,* His removal from among us will prove an irreparable loss to the world and to his friends to whom he has been throughout his professional life so assiduously devoted, and

"*Whereas,* We desire to express our deep appreciation of his upright and manly character as a citizen and engineer. He was thorough, careful, reliable, honorable, and conscientious, and one who was never swerved from the path of

rectitude by fear or favor. As a straightforward citizen, he set a noble example for the young of all classes and, particularly, to the members of his chosen profession.

"Therefore, Be it Resolved, That these resolutions be spread upon the minutes of this Society and a copy sent to his family as our expression of sympathy and condolence in their affliction.

"'We cherish the memory of his noble character, his lofty patriotism, and the wisdom of his counsel. We that loved him so, followed him and honored him and made him our pattern to live and to try'."

Mr. Wheeler was elected a Member of the American Society of Civil Engineers on December 7th, 1904.

SEBASTIAN WIMMER, M. Am. Soc. C. E.*

DIED NOVEMBER 30TH, 1921

Sebastian Wimmer, the son of George and Theresia (Hahn) Wimmer, was born at Thalmassing, near Ratisbon, Bavaria, Germany, on January 5th, 1831. His father was a hotel proprietor at Thalmassing, but removed to Munich in 1833, where the son was graduated from the Technical and Polytechnic Schools. He also took an engineering course at the latter in 1850-51.

On June 2d, 1851, Mr. Wimmer, with his uncle, the late Archabbot Boniface Wimmer, O.S.B., arrived in New York City. He went from there to Pittsburgh, Pa., where he was graduated from the Iron City College, having taken a course in bookkeeping and business methods.

He began the practice of his profession in the United States with the engineering firm of Hastings and Preisser, of Pittsburgh, Pa., with which the writer's father, the late Sigismund Low, was also associated. Messrs. Wimmer and Low were intimate friends, whose acquaintance lasted many years.

From Pittsburgh, Mr. Wimmer went to New Orleans, La., where he remained for six months, returning to Pittsburgh, in 1853. He then secured from the late W. Milnor Roberts, Past-President, Am. Soc. C. E., Chief Engineer of the Allegheny Valley Railroad, an appointment as Assistant Engineer in charge of the Division between Pittsburgh and Kittaning, a distance of 45 miles. He was engaged on this work until October, 1856, when he went to Minnesota. Soon after locating at St. Paul, he was appointed Assistant Engineer of the Faribault Division of the Minneapolis and Cedar Valley Railroad (now the Chicago, Milwaukee, and St. Paul Railroad), after locating the line from Minneapolis to Mendota, *via* Fort Snelling.

From Minnesota, Mr. Wimmer returned to Pittsburgh, where he left his family, and again went to New Orleans with the idea of locating there, but, on account of his health, he was forced to give up his plans. Returning to Pittsburgh, he accepted the position of bookkeeper at St. Vincent's Abbey, Westmoreland County, Pennsylvania, where he was instrumental in having a telegraph office and post-office established and where he served as the first Postmaster.

* Memoir prepared by Emile Low, M. Am. Soc. C. E.

In 1861-63, under Thomas Seabrook, he made the survey for the Allegheny Valley Railroad from Garland to Oil City, Pa., and northward from Titusville. In June, 1863, he was transferred to St. Marys, Pa., to take charge of the Edward Miller and Milton Courtwright Contract, to complete the Philadelphia and Erie Railroad from Whetham, west of Lock Haven, to Warren, Pa., a distance of 143 miles.

This work having been completed early in 1865, Mr. Wimmer went to New York City, where, on March 6th, 1865, he met Gen. S. V. Talcott, a relative of Capt. Andrew Talcott, Chief Engineer of the Imperial Mexican Railway, and secured an appointment on this railway, which, at the time, was under construction between Vera Cruz and the City of Mexico, 264 miles, exclusive of the Puebla Branch.

Mr. Wimmer was assigned to the heavy construction work on what is known as the Maltrata Incline, the heavy grade line between Orizaba and Boca del Monte. He sailed from New York City on March 29th, 1865, arriving at Vera Cruz on April 13th. At that time, the railway was in operation as far west as Paso del Macho (Mule Pass), 48 miles. Leaving Vera Cruz on April 16th, 1865, Mr. Wimmer reached the railroad terminus after a three hours' journey. The trip from Paso del Macho to Orizaba, 34 miles, was made by stage coach, and Mr. Wimmer arrived at the latter place on the morning of April 17th. Orizaba, then a city of 22 000 inhabitants, was the headquarters of both the engineers and the contractors.

Capt. Talcott arrived from the City of Mexico on April 25th, 1865, in company with Mr. William Lloyd, of London, England, who was Chief Engineer for the Contractors, Smith, Knight and Company, and on April 26th, the party, with Mr. Wimmer, traveled on horseback to Maltrata. The next day they rode to Boca del Monte (mouth of the mountain), the head of the grade, returning to Maltrata the same evening. Mr. Wimmer had been placed in charge of Sections 1-7 (seven miles), comprising the very heavy work of the upper end of the Maltrata Incline, superseding Mr. Fred Simon, an English engineer.

Emperor Maximilian, on a tour of inspection of the railroad, arrived at Maltrata on April 29th, 1865, and was entertained at dinner by the chief contractors, Smith, Knight, and Company. During this dinner, he was apprised of the assassination of President Lincoln, and, with a number of the engineers, left immediately for Orizaba.

On Sunday, April 30th, Mr. Wimmer attended church with the Emperor, and, later, left for Maltrata, to take charge of his assignment. His first headquarters, at Boca del Monte, were in a shanty which housed from 20 to 30 mules and also served as a powder magazine. On July 20th, 1865, he moved to new quarters, at the site of Wimmer Bridge Section 5, and his first work was the taking of the regular monthly estimate. The center line had been run, but he had to make frequent changes in the alignment, introducing curves of 350-ft. radius, in order to reduce the work. One of these points was at Wimmer Bridge, another at the Twin Barrancas, where he located a tunnel through a projecting spur, in order to reduce two large embankments which would have required "millions" of cubic yards of material. In Mexico, the wet season

occurs in June, July, August, and September, and during this period enormous slides gave much trouble.

Routine work kept Mr. Wimmer busily employed, the monotony being varied by frequent inspections by the engineers of the Railroad Company, as well as those of the Chief Contractors. Other incidents were guerrilla scares, the murders of sub-contractors by soldiers of the Liberal Government, earthquakes, etc. The Empress Carlotta also visited Orizaba on December 25th, 1865, an entertainment being given in her honor.

Owing to financial difficulties, the railway work was considerably curtailed in the spring of 1866, and Mr. Wimmer procured a leave of absence to visit the United States, arriving at New York City on June 13th. He returned to Mexico in September and proceeded at once to Maltrata. On October 23d, he was ordered to the City of Mexico to compile an estimate of the amount of work done by the contractor between Paso del Macho and Boca del Monte, 59.5 miles. This work occupied two months, and on January 3d, 1867, Mr. Wimmer returned to Maltrata to take up his routine duties. Military operations between the contending forces of Emperor Maximilian and the Mexicans were in progress at this time and virtually compelled the abandonment of railroad construction.

Having received orders to proceed to London, England, in the interest and pay of the Chief Contractor, Mr. George B. Crawley, Mr. Wimmer, in the company of many of the engineers, contractors, and their families, left Orizaba on April 30th, 1867, for Paso del Macho, which place was reached after many delays. Mr. Wimmer had with him such maps, profiles, documents, and papers, relating to the work, as were essential for the computation of quantities and the determination of the moneys due the contractor.

On May 1st, 1867, the party left Paso del Macho, on an open flat car. Owing to the ascending grade to Cameron, eight miles, they had to hire Indians to push the car to the summit, and from there they dashed down grade eastward at great speed, as the brake on the car would not work properly. They passed through Soledad and up the next grade, where, fortunately, they were able to control the speed, to Tejeria, 10 miles out of Vera Cruz, where the railroad trestle over the barranca had been burned. From Tejeria, they telegraphed Gen. Benavides, at Casa Mata, in the outskirts of Vera Cruz, who sent them a car on which they reached Casa Mata.

Mr. Crawley and others called on Gen. Benavides, to present instructions from Gen. Porfirio Diaz (at the time besieging the City of Mexico) to allow the party to leave Mexico for England. The members of the party were then taken to Medellin, and on May 3d, they left Medellin in Indian canoes for Boca del Rio, 9 miles down the river, arriving there safely. Owing to some mistake of Gen. Benavidas, Mr. Wimmer's name and that of Mr. John E. Weidenborner were omitted from the list of those permitted to leave Mexico, and they were not allowed to board the steamer, the *Jason,* with the party, although Mr. Wimmer had a United States passport signed by the Secretary of State.

On hearing of their plight (they were without money, except for an ounce of gold which Mr. Wimmer happened to have in his pocket, clothes, etc.), Mr. Crawley got in communication with Gen. Benavides, and, finally, a boat flying

the American flag appeared at Boca del Rio, and to their great joy, was permitted to take Messrs. Wimmer and Weidenborner on board. They were then put aboard the *Jason,* but, afterward, Mr. Wimmer and Mr. Weidenborner left the *Jason* for the U. S. Steamer, *Virginia,* which sailed at once for Havana, reaching that city on May 10th, 1867. Mr. Wimmer left Havana shortly afterward for New Orleans, and went from there to Philadelphia, Pa., arriving at that city on May 25th, 1867.

On June 26th, 1867, Mr. Wimmer left New York City for London, England, to compile the final estimate and adjust the accounts of Mr. Crawley, the General Contractor for the Imperial Mexican Railway. This work was completed on August 9th, 1867, after which Mr. Wimmer visited the Paris Exposition and relatives in Bavaria, Germany, and returned to the United States in November. While at the Paris Exposition, he received a telegram from the London Railway Office, requesting him and Mr. Thomas Braniff to return to Mexico. But he declined the offer. Mr. Wimmer's name is indelibly associated with the Imperial Mexican Railway by having one of the bridges (Puente de Wimmer) on the Maltrata Incline named for him.

On his return to the United States, Mr. Wimmer received an offer from the late George B. Roberts, First Vice-President of the Pennsylvania Railroad, of a position on a line to be built by that Company from Driftwood to Dubois, Pa. (low grade), which he accepted.

From 1868 to 1874, Mr. Wimmer was in charge of the construction of the Bennetts Branch Extension of the Philadelphia and Erie Railroad, afterward known as the Low Grade Division of the Allegheny Valley Railroad, with headquarters at St. Marys, Pa. Frank M. Ashmead, M. Am. Soc. C. E., who was connected with this work in 1871-72-73, writes:

"Mr. Wimmer was pretty constantly in the field, and scarcely a week passed that he did not ride on horseback from St. Marys to Caledonia and the further twenty miles to Summit Tunnel, so that with that and the further ride on horseback of one or another of our party through the twenty miles to the St. Marys office, we had ample opportunity to become well acquainted with what I can candidly say was one of the noblest characters I have ever met in a long business life. This refers to his personal goodness of disposition. I think everybody liked Mr. Wimmer. As for his technical training and complete fitness to lead in constructive work, such as that upon which we were engaged at that time, I think we all bowed to his superior knowledge, although I believe a number of us younger recruits had been trained in technical colleges."

In 1874, Mr. Wimmer was elected to represent Elk County in the Pennsylvania State Legislature, and served for two terms, during which he was Chairman of the Railroad Committee, Secretary of the Committee on Counties and Townships, and a member of the Centennial Committee. In 1876, Mr. Wimmer was a Presidential Elector for Tilden and Hendricks.

From 1877 to 1879, he was engaged as Chief Engineer of the Pittsburgh and Lake Railroad, a line built by the so-called Economite Society, between Pittsburgh, Pa., and Youngstown, Ohio. Samuel Rea, Hon. M. Am. Soc. C. E., now President of the Pennsylvania System, served on this work under Mr. Wimmer.

From 1879 to 1882, he was the Chief Engineer of the New York and Northern Railroad, extending from High Bridge to Brewsters, N. Y., with an office in New York City. In the summer of 1882 (August and September), Mr. Wimmer went to Mexico as a representative of a New York Syndicate to examine the Mexican Central Railway then building. From late in 1882 to 1884, he served as Chief Engineer in charge of construction of the Erie and Wyoming Valley Railroad, from Hawley to Avoca, Pa. Returning to New York City, he built the Yonkers Rapid Transit Railway, reported on a line between Turner (Newburgh Junction), on the Erie Railroad, and Danbury, Conn. He also located lines in Elk and Clearfield Counties, Pennsylvania, for the Pittsburgh, Shawmut, and Northern Railroad.

In 1904, Mr. Wimmer was appointed Associate Chief Engineer of the Wabash Railway, comprising the Pittsburgh, Carnegie, and Western Railway, from Pittsburgh to the Ohio River, and the Pittsburgh, Toledo, and Western Railway, from the Ohio river to the connection of the Wheeling and Toledo Railway, in Harrison County, Ohio. This was one of the most difficult pieces of railroad construction in the United States, having seventeen tunnels, varying in length from 200 to 4 700 ft., and many iron bridges, including two exceptionally long ones over the Monongahela and Ohio Rivers. This work will ever stand as a monument to his integrity as an engineer.

In 1907, Mr. Wimmer left St. Marys, where he had maintained his residence since 1863, and went to Albany, Minn., where he resided on his farm until about 1919. He then returned to St. Vincent's Abbey, at Beatty, Pa., which had been founded by his uncle and of which he had been the first Archabbot, to spend his remaining years. His death occurred there on November 30th, 1921, after weeks of patient suffering.

On February 12th, 1857, Mr. Wimmer was married to Miss Lavinia Blakely, of Pittsburgh, Pa. To this union three sons were born, Dr. Sebastian J. Wimmer, Ernest J. Wimmer, an attorney, and William Wimmer. The latter two, with the wife and mother, preceded Mr. Wimmer to the grave. The surviving son, Dr. Wimmer, is a special representative for the Standard Oil Company.

Mr. Wimmer was one of those men of whom the world sees too few, and all those who came in contact with him know his real great worth.

Mr. Wimmer was elected a Member of the American Society of Civil Engineers on March 2d, 1881, and at the time of his death was the oldest member of the organization.

GEORGE ROBERT DAVIS, Assoc. M. Am. Soc. C. E.*

Died March 31st, 1922.

George Robert Davis was born in Riverside, Calif., on October 17th, 1877. At the age of 20, he joined the United States Geological Survey in the capacity of Traverseman, at Elsinore, Calif. In 1912, he was promoted to

* Memoir prepared by H. C. Rizer, Chf. Clerk, U. S. Geological Survey, Washington, D. C.

the position of Topographic Engineer in charge of the Pacific Division of the Survey, which includes the States of Washington, Oregon, California, Utah, Arizona, and the Territory of Hawaii, a position which he held until his death, at San Francisco, Calif., on March 31st, 1922.

He is survived by his wife, Mrs. Adelena Marie Fontaine Davis, and a daughter.

During the years of his service with the Government, Mr. Davis surveyed much unexplored territory in the Western States and was recognized as an expert Topographic Engineer. Included in his work of topographic surveying was the mapping of the Mount Whitney, Mount Goddard, Bakersfield, and McKittrick Quadrangles, in California, as well as mapping in the Yosemite National Park, and King's River Canyon, California, in Mt. Rainier National Park, Washington, in the Territory of Hawaii, and many other areas. Mr. Davis has thus indelibly imprinted his lifework on some thirty Government maps portraying the highest type of topographic mapping. In his death, Geographic Science has sustained a distinct loss.

Mr. Davis was a Fellow of the American Geographical Society, a member of the National Geographic Society, the Sierra Club of San Francisco, the City Club of Washington, the Sutter Club of California, and of Evergreen Lodge, F. and A. M., of Riverside, Calif. In 1915, he was a Government delegate to the International Engineering Congress in San Francisco and, in 1920, a delegate to the Pan-Pacific Scientific Congress in Honolulu, Hawaii.

Mr. Davis was elected an Associate Member of the American Society of Civil Engineers on April 3d, 1907.

CLIFFORD MARSHALL KING, Assoc. M. Am. Soc. C. E.*

Died January 2d, 1922.

Clifford Marshall King, the son of Judge and Mrs. Edmund B. King, was born in Sandusky, Ohio, on December 17th, 1879.

He received his elementary education in the Sandusky schools and at Oberlin Academy. In September, 1897, he entered Adelbert College, Western Reserve University, at Cleveland, Ohio. In April, 1898, he enlisted in the Army and served as Battalion Sergeant Major of the Second Battalion, 6th Regiment, Ohio Volunteer Infantry, until September, 1898, when he was honorably discharged by order of President McKinley. Mr. King received his B. A. Degree from Western Reserve in 1901, and in the same year, entered Cornell University, from which he was graduated with the degree of Civil Engineer in 1904. He received Sigma Xi honors and was a member of the Alpha Delta Phi Fraternity.

After his graduation and until 1907, Mr. King was Assistant Engineer in the United States Reclamation Service and Deschutes Irrigation and Power Company. From January, 1908, until the latter part of 1912, he served as

* Memoir prepared by George B. Gascoigne and Robert Hoffmann, Members, Am. Soc. C. E.

City Engineer of Sandusky, Ohio. After completing his terms as City Engineer, and up to the time of his taking office as County Engineer of Erie County, Ohio, in January, 1915, he devoted his time to the general practice of Civil Engineering in his own office in Sandusky.

Mr. King served as County Engineer for two years and then entered the U. S. Army as Captain in the Engineer Corps. After receiving his honorable discharge from the Army in 1919, he entered the employ of the City of Cleveland as Assistant Engineer in charge of design in the Sub-Division of Sewage Disposal, in which position he remained until his death on January 2d, 1922. Just prior to his death, he had made arrangements to become associated in private engineering practice with George B. Gascoigne, M. Am. Soc. C. E., in a position similar to that which he held with the City of Cleveland.

He is survived by his widow, Edith Davis King, his parents, and one sister.

Mr. King was an ardent patriot and in 1895 began his military training with enlistment in Company B, 16th Regiment, Ohio National Guard. In 1898, as stated, he was in the Federal Service during the Spanish-American War and when the United States entered the World War, Mr. King was among the first to offer his services. He was commissioned as Captain in the Engineer Reserve Corps on August 27th, 1917, and soon after entered the Second Engineer Officers' Training Camp. After receiving his commission, he served as Assistant to the Division Engineer, 88th Division, and was detailed as Instructor of Field Fortifications at the Third Officers' Training Camp at Camp Dodge, Iowa. Soon afterward he was assigned to the 528th Engineers and was Commander of Company B from April, 1918, to March, 1919, when he was promoted to Commander of the Battalion which office he held until the time of its demobilization at Camp Gordon, in July, 1919. He served in France from July, 1918, to June, 1919.

Mr. King thoroughly enjoyed his military experiences and had such a complete grasp of the details of the various movements in France that after his return it was most instructive and entertaining to listen to his explanations of the accomplishments of the Field Armies.

As a Civil Engineer, Mr. King has left work in and around Sandusky, which will stand to his credit for many years to come. This applies particularly to the Cedar Point Chaussée and various highways and bridges in which he specialized.

In his professional service, he was conscientious and painstaking to the last degree. His ability to apply himself to a problem showed a power of concentration possessed by few. He was an untiring worker and would never rest until the task at hand was completed.

Although quiet and reserved by nature, Mr. King nevertheless had a keen sense of humor. His politeness and chivalry were noted by every one who had occasion to meet him socially. To those who knew him intimately, he had a personal charm that made him not only highly respected but greatly beloved as well. His passing leaves a gap in the ranks of his many friends

who knew him in all circumstances as a man of sterling character and high ideals.

He always kept abreast of the times and identified himself with various professional societies. He was a member of the American Association of Engineers, the Ohio Engineering Society and the American Society of Military Engineers. In addition to the professional societies, he was a member of the City Club of Cleveland and also of various Masonic bodies, in all of which he had attained a high degree of eminence.

Mr. King was elected a Junior of the American Society of Civil Engineers on March 6th, 1906, and an Associate Member on July 1st, 1909.

EMERET CLAUDE NEUDECKER, Assoc. M. Am. Soc. C. E.*

Died June 8th, 1921.

Emeret Claude Neudecker, the son of Frank and Lavina (Powers) Neudecker, was born at Madison, N. Y., on June 8th, 1885. His early education was obtained at Oriskany Falls Union, New York, and at Colgate Academy, from which he was graduated in June, 1906. He received his technical education at the Clarkson College of Technology, from which he was graduated in the Class of 1911.

From July, 1911, to February, 1918, Mr. Neudecker was with the New York State Engineer at Albany, N. Y. Starting as Chainman, he was promoted through the grades of Rodman, Leveler, Timekeeper, Transitman, Inspector, and Junior Engineer, and on April 1st, 1917, reached the grade of Junior Assistant Engineer.

From March 1st to December 22d, 1918, he was employed as Chief of Party for the Mellon-Stuart Company, his work consisting of giving grades and locations for the construction of a permanent hospital unit at Edgewood Arsenal, Edgewood, Md.

From December 22d, 1918, to March 22d, 1920, Mr. Neudecker was with the Shipbuilding Realty Corporation, at Newport News, Va., as Chief of Party. As such, his work consisted of giving grades and locations for all main sewers, sewage disposal plant, storm drains, walks, curbs, and gutters for the Hilton Village Housing Project. Later, he assisted in making the final record maps of this work.

Mr. Neudecker began his work for the Iowa Highway Commission on June 1st, 1920, as Instrumentman on surveys. He continued with the Commission on various work, until his death on June 8th, 1921. On December 9th, 1920, he was transferred to District Headquarters at Storm Lake, Iowa, where he was engaged in preparing plans for road construction for the State. On April 1st, 1921, he was transferred to Humboldt, Iowa, as Resident Engineer on grading and paving, and he was located at Humboldt at the time of his death.

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* Memoir prepared by J. F. Reynolds, Assoc. M. Am. Soc. C. E.

On July 15th, 1913, Mr. Neudecker was married to Sarah E., daughter of Willard Bruce and Lephe L. Sprague, of Canton, N. Y., who died in May, 1918. A daughter, Sarah Frances, survives him.

Mr. Neudecker was a man of the conservative type. He was one of the few men who actually have more ability than they themselves realize. While in Iowa, he established a reputation as a careful, accurate engineer, in recognition of which he was given the important assignment at Humboldt. He numbered among his friends all his associates in the highway work, and his sudden death was a shock to his friends in Iowa and his relatives in New York State.

Mr. Neudecker was elected an Associate Member of the American Society of Civil Engineers on April 19th, 1920.

ABRAHAM JOHN RUTH, Assoc. M. Am. Soc. C. E.*

Died November 3d, 1921.

Abraham John Ruth, the son of Daniel and Anna Ruth, was born in St. Clair County, Illinois, on April 6th, 1874. He was educated at the University of Kansas, from which he was graduated in 1901, with the degree of B. S. in Civil Engineering.

During his summer vacation in 1900, Mr. Ruth served as Topographer on a railway survey in Arkansas. After his graduation, in June, 1901, he entered the employ of the American Bridge Company, at Trenton, N. J., as Draftsman on the detailing of steelwork, but he resigned in April, 1902, to accept a position as Draftsman in the Bridge and Building Department of the Chicago, Milwaukee, and St. Paul Railway Company, at Chicago, Ill. In this capacity, he was engaged on the design and detailing of steel and masonry work, having had charge for one year of masonry design for the Department.

In August, 1904, Mr. Ruth went to the Pacific Coast, and entered the service of the Southern Pacific Company, having been engaged on maintenance-of-way and office work on the Los Angeles Division.

In July, 1905, he was appointed Assistant Engineer and Chief Draftsman in the Railway Department of the Cananea (Mexico) Consolidated Copper Company, and was engaged on the design of bridges, structures, machines, etc., and also assisted in superintending their construction. In February, 1911, he was also given charge of the Mechanical Drafting Room of the Company, and from June, 1912, to 1913, he served as Chief Engineer in charge of engineering and construction work. In 1913, Mr. Ruth entered the service of the Arizona Copper Company, with which Company he remained for several years. He was also engaged in the automobile business for a number of years.

On January 1st, 1921, he went to Tampico, Tamps., Mexico, in the employ of the Huasteca Petroleum Company, with which Company he served until his death on November 3d, 1921.

* Memoir prepared from information furnished by H. H. Willis, Assoc. M. Am. Soc. C. E., and on file at Society Headquarters.

He was married on December 25th, 1902, to Emma C. Eymann, who, with three daughters and one son, survives him. He is also survived by his father, eight brothers, and three sisters.

Mr. Ruth was elected an Associate Member of the American Society of Civil Engineers on March 4th, 1913. He had also been a member of the Western Society of Engineers.

EDMUND ABIEL THORNTON, Assoc. M. Am. Soc. C. E.*

Died January 9th, 1922.

Edmund Abiel Thornton, the only son of Thomas M. and the late Flora (Thorne) Thornton, was born at Stoneham, Mass., on September 13th, 1883. While still a boy in the Grammar School, the long and serious illness of his father, brought him early responsibility and served to develop the strong traits of industry and perseverance that persisted in his character during the remainder of his life. In these earlier school days, he ranked high as a scholar, and, to an unusual degree, sought to apply the knowledge gained from his studies to the problems of his daily life. He was graduated from the Stoneham High School in 1903 as Valedictorian of his class.

After his graduation from High School, Mr. Thornton passed the entrance examinations for the Massachusetts Institute of Technology, winning a scholarship. He selected the course in Civil Engineering and close application to his studies won him other scholarships which, together with field work in his profession during summer vacations, enabled him to pay his expenses through the four years required for the completion of the course. He was graduated in 1907 with the degree of Bachelor of Science.

In July, 1907, Mr. Thornton entered the employ of the Randolph Lines (Southern Pacific of Mexico), as Assistant to the Office Engineer in Tucson, Ariz. He remained in this position until April, 1909, when he resigned to enter the employ of the Ray Consolidated Copper Company at Ray, Ariz., as Draftsman.

When he had been for about one year with the Ray Consolidated Copper Company, he was appointed Engineer on development work at No. 2 Mine, which is now the principal producing unit of the Company. While holding this position, Mr. Thornton made many important surveys, and detailed the timbering and track work for all the main haulage drifts in the mine. The exceptional accuracy and keen perception which he displayed in attacking the many difficult problems that came to him for solution during this period, could not fail to win the appreciation of his superiors, and, in January, 1914, he was placed in charge of all the surface engineering at the mines as well as of maintenance of way of the Ray and Gila Valley Railroad.

During 1914 and 1915, he planned and carried out numerous important surface improvements which the expanding plant and the rapidly growing community made necessary. It was, also, during this period, that he made preliminary surveys and studies for the flood control and diversion of Mineral

* Memoir prepared by Moses Brown, Jr., Esq., Ray, Ariz.

Creek, and the result of these studies was an effective solution of what had previously been a serious problem to both the mines and the railroad.

On May 1st, 1916, Mr. Thornton was appointed to the position of Chief Engineer and this well-deserved promotion gave him broader scope in which to demonstrate his unusual ability. At that time, the Ray Consolidated Copper Company, as well as all the copper mines, was forcing production to the utmost in order to meet the tremendous demand for copper created by the World War. With the entrance of the United States into the conflict, came the necessity of still further increase in production at the time when the draft was taking away from the working force, many of the trained men who could not easily be spared. That the Ray Consolidated Copper Company was able to meet this emergency successfully, was due, in no small measure, to the efficient manner in which Mr. Thornton directed the work of his Department. His fitness for a still higher position was recognized and, on February 1st, 1918, he was appointed Assistant Superintendent of Mines, which position he still held when his career was brought to an untimely end on January 9th, 1922.

During the last year of his life, Mr. Thornton suffered from an illness which he bore with great fortitude and which, with characteristic bravery, he concealed even from his most intimate associates. Without doubt, persistent application to his work at this time had much to do with hastening his death. In July, 1921, he returned to his old home in Stoneham, Mass., in the hope that a long rest under skillful medical treatment would restore him to health, but, unfortunately, this object was not realized. It was typical of the man that, up to the last day of his life, he spent much of his time in study.

In 1911, Mr. Thornton was married to Miss Louise J. Parkhurst, who, with a son, William Randolph Thornton, and his father and sister, survives him.

As an engineer, Mr. Thornton was a man of exceptional ability, and a close student of all that pertained to his profession. He was far-seeing, yet practical. In everything he attempted, he showed himself possessed of an energy and power of will which could not fail of ultimate achievement.

As a man among men, he was modest and unassuming, but, whenever occasion required, he was a fearless, straightforward fighter for the cause of justice and right. Clean-minded and honorable in all things, devoted to his family, loyal to his friends and employers, he was loved and respected by all who knew him.

Mr. Thornton was elected an Associate Member of the American Society of Civil Engineers on November 4th, 1914.

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The Committee on Publications will be glad to receive communications of general interest to the Society, and will consider them for publication in *Proceedings* in "Items of Interest". This is intended to cover letters or suggestions from our membership concerning matters which are not of a technical character. Such communications, however, must not be controversial or commercial.

Change of Date for Issuing *Proceedings*

This number of *Proceedings* is the first to be published in pursuance of a new policy in regard to the date of issue.

Heretofore, the *Proceedings* have been issued on the fourth Wednesday of each month, except June and July. In the future, the *Proceedings* of any month will be issued on the last day of the preceding month, for example, the September number is issued on the 31st of August.

For this reason, the minutes of the meeting of the Society of September 6th, 1922, will appear in the October *Proceedings*.

Honorary Members Elected

At the meeting of the Board of Direction on June 19th, 1922, the Tellers appointed to canvass the Ballots for Honorary Members reported the election of Leon-Jean Chagnaud, Sir Maurice Fitzmaurice, Clemens Herschel, Past-President, Am. Soc. C. E., John F. Stevens, M. Am. Soc. C. E., and W. C. Unwin, as Honorary Members of the Society. The following brief sketches of their lives and work are presented herewith for the information of the membership.

Leon-Jean Chagnaud

Leon-Jean Chagnaud was born at Le Bourg d'hem, in the Department of Creuse, France, and in 1881 entered the École des Arts et Métiers at Chàlons sur Marne. Soon after his graduation he reconstructed the locks of the Canal du Centre and established the massive concrete fortifications about Toul. He also built 11 km. of strategic roads between Vitry and Blesmes.

Charged with the execution of subterranean excavation (the "Collecteur de Clichy", one of the large trunk sewers of Paris) in the center of Paris and its outlying Districts, a work carried on at a minimum depth of 1 m. below the surface and without interruption to traffic, he was largely responsible for the development of the modern method of shield tunneling for subterranean and subaqueous excavation. It was the first use of this method in Paris.

The tunnels for crossing the Alps at Loëtschberg and Moutier-Longeau were planned and executed by M. Chagnaud, a difficult undertaking on account of the danger from avalanches.

On the construction of the Métropolitain Line No. 4, in Paris, from the Porte de Clignancourt to the Porte d'Orleans that crosses under the two branches of the Seine and under the Isle de la Cité, he sank the huge shafts at the Place St. Michael and the Cité Stations, which were sunk as caissons and utilized to form the permanent lining. For the execution of this difficult construction, which required freezing of the soil and injections of cement in certain sections, he was rewarded by the Prix Berger and the bestowal of the Legion d'Honneur.

M. Chagnaud has served the State as a Member of the Senate, and, in 1921, was the President of the Société des Ingénieurs Civils de France.

Sir Maurice Fitzmaurice

Sir Maurice Fitzmaurice was born on May 11th, 1861. He was educated at Trinity College, Dublin, receiving degrees of M. A. and M. E. (Dublin), and LL. D. (Birmingham). He was apprenticed to the late Sir Benjamin Baker, Hon. M. Am. Soc. C. E. From 1901-12 he was Chief Engineer to the London County Council and, from 1912 to 1918, served as Chairman of the Admiralty Advisory Committee on Naval Works. From 1914-19, he was Chairman of the Committee dealing with Civilian Labor, London Defences (War Office), and from 1917-19, he acted as Chairman of the Canal Control Committee

(Board of Trade). He was also a Member of the War Office Committee on Hutted Camps and from 1918-19 was Chairman of the Nile Projects Committee (Foreign Office). In 1919, he also served as Chairman of the Committee on Aerodrome Accounts (Treasury). He was also a Member of the Advisory Council of the Science Museum. He acted as Engineer of the Rotherhithe Tunnel, New Vauxhall Bridge, Kingsway and Tramway Subway, the Electric Tramways in London, and the duplication and extension of the London Main Drainage System and as Senior British Engineer on the Suez Canal Commission. In 1913, at the request of the Commonwealth Government, he visited Australia to advise on Naval Harbors and Works. Sir Maurice was a Lieutenant-Colonel in the Engineer and Railway Staff Corps, and in 1915 and again in 1918, he visited the British front in Flanders at the request of the War Office, to advise on questions of drainage. He was also engaged on the Forth Bridge and was consulted regarding railways and docks in Canada, the Blackwall Tunnel, and the Nile Reservoir Dam, Assouan, Egypt. From 1916-17 he served as President of the Institution of Civil Engineers. He is also a Member of the Institution of Mechanical Engineers, Honorary Fellow of the Society of Engineers, Honorary Member of the Royal Engineers Institution, Member of the Canadian Institute of Engineers, Vice-Chairman of the Engineering Standards Committee, Vice-Chairman of the Institute of Transport, and Member of the Advisory Council on Scientific and Industrial Research. He was knighted in 1912. He has also received Orders, Medals, etc., as follows: C. G. M., 1902; F. R. S., 1919; Order of Mejidieh, Second Class, 1901; and the Telford and Watt Gold Medals of the Institution of Civil Engineers. He is the author of books on "Plate Girder Railway Bridges". "The Thames and Lea", "London County Bridges", "Main Drainage of London", and many papers.

Clemens Herschel

Clemens Herschel, Past-President, Am. Soc. C. E. (Director, 1891; Vice-President, 1915-16; President, 1916), was born in 1842. He was graduated from the Lawrence Scientific School of Harvard University in 1860. He then went abroad to pursue further engineering studies in France and Germany.

Returning to the United States, he undertook a variety of engineering work chiefly in New England, giving much attention to bridge work and, in 1875, he published a treatise on continuous revolving draw-bridges. He was connected at one time with the Boston Sewer Department and served for two years as a Member of the Massachusetts Railroad Commission. After a period of service under the late James B. Francis, Past-President, Am. Soc. C. E., he was appointed, in 1879, to the position of Hydraulic Engineer of the Holyoke Water Power Company. He constructed the famous Holyoke Testing Flume, and established a system of metering and of recording the water consumption of the turbines in the Holyoke Mills. The need of an instrument for accurately measuring the flow of water in large pipes led to his invention of the Venturi Meter, which was described in a paper entitled "The Venturi

Water Meter: An Instrument Making Use of a New Method of Gauging Water; Applicable to the Cases of Very Large Tubes, and of a Small Value Only, of the Liquid to be Gauged", presented before the Society at the meeting of December 21st, 1887, and published in *Transactions* Vol. XVII, for which he received the Thomas Fitch Rowland Prize in 1888. He also received the Elliott Cresson Gold Medal of the Franklin Institute, Philadelphia, Pa., for his work on the Venturi Water Meter.

In 1889 he was made Chief Engineer of the East Jersey Water Company, which was then embarking on a large enterprise for the supply of potable water to the cities and towns of Northern New Jersey. He was Consulting Engineer for the Niagara Falls Power Company, and was a Member of the Commission that made a report on the practicability of the deep rock tunnel plan of distribution of the Catskill Water in New York City. He was employed by the United States Government to investigate and report on the development of water power at Great Falls on the Potomac River.

He served as Treasurer of the Boston Society of Civil Engineers from 1874 to 1880, and was President of that Society in 1890-91. He is also a Member of the Institution of Civil Engineers of Great Britain.

He has published a translation of "Frontinus, and his II Books on the Water Supply of the City of Rome, A. D. 97". The "115 Hydraulic Experiments", another treatise on hydraulics, was published by Mr. Herschel in 1897.

John Frank Stevens

John Frank Stevens, M. Am. Soc. C. E., was born in West Gardiner, Me., on April 24th, 1853.

He was Assistant Engineer, City of Minneapolis, Minn., from 1874 to 1876; became Chief Engineer of the Sabine Pass and Northwestern Railway in 1876; and acted as Assistant Engineer for the Denver and Rio Grande Railway in 1879, and the Chicago, Milwaukee and St. Paul Railway from 1880 to 1882.

Mr. Stevens acted as Division Engineer for the Canadian Pacific Railway from 1882 to 1886, when he returned to the Chicago, Milwaukee and St. Paul Railway as Assistant Engineer. From 1887 to 1889, he was Principal Assistant Engineer of the Duluth, South Shore and Atlantic Railway, when he became Assistant Engineer of the Spokane Falls and Northern Railway.

Mr. Stevens became Principal Assistant Engineer with the Great Northern Railway in 1889, and was successively promoted to Assistant Chief Engineer in 1893, Chief Engineer in 1895, and General Manager in 1902. In 1903, he joined the staff of the Chicago, Rock Island and Pacific Railway Company as Chief Engineer, and became Second Vice-President in 1904.

From 1905 to 1907, Mr. Stevens was Chief Engineer of the Panama Canal; and, in 1907, he acted as Chairman of the Isthmian Canal Commission.

In 1907 he became Vice-President of the New York, New Haven and Hartford Railroad and had charge of operation. From 1909 to 1911, he became President successively of the Spokane, Portland and Seattle Railway, the

Oregon Electric Railway, the Oregon Trunk Railway, and the Pacific and Eastern Railway. He was head of the American Railway Mission to Russia in 1917, and acted as Director of a Corps of Railway Experts in Manchuria.

Mr. Stevens is an Honorary Member of the Association of Chinese and American Engineers, and President of the Inter-Allied Technical Board supervising the technical and economic operation of the Siberian and Chinese Eastern Railway, with headquarters at Harbin, Manchuria.

William Cawthorne Unwin

William Cawthorne Unwin was born on December 12th, 1838, at Coggeshall, Essex, England. He was educated at the City of London School and was a pupil of the late Sir William Fairbairn. From 1861-68, he was Manager of Engineering Works, and from 1868-72, was Instructor at the Royal School of Naval Architecture and Marine Engineering, Kensington. From 1872-85, he was Professor of Hydraulic Engineering, Royal Indian Engineering College, Cooper's Hill and from 1884-1904 he was Professor of Engineering, Central Technical College of the Guilds of London, Kensington. He was also Secretary of the International Commission on the Utilization of Niagara, and in 1892 was President of Section G of the British Association. In 1894 Professor Unwin was a member of the Council of the Royal Society and in 1911, he was President of the Institution of Civil Engineers. He also served in 1915-16 as President of the Institution of Mechanical Engineers. From 1915-18 he was a Member of the Management Board of the Metropolitan Munitions Committee. From 1900 to 1905 and since 1911 he has served on the Senate of London University. Mr. Unwin was awarded the Kelvin Medal in 1921, and has had conferred on him the degree of LL. D. from Edinburgh, is a Fellow of the Royal Society; Member of the Institution of Civil Engineers; Honorary Life Member of the Institution of Mechanical Engineers; Honorary Member, American Society of Mechanical Engineers; and Honorary Associate of the Royal Institution of British Architects. He has published books on "Wrought Iron Bridges and Roofs" (1869), "Machine Design" (1877), "Testing of Materials of Construction" (1888), "The Development and Transmission of Power from Central Stations" (1894), "Treatise on Hydraulics" (1907), and has contributed articles on Hydraulics and Bridges for the Encyclopedia Britannica. He is Professor Emeritus of the Central Technical College, City and Guilds of London Institute.

Holland Engineers Honor Dr. Chas. Warren Hunt

The Koninklijk Instituut van Ingenieurs (Royal Society of Engineers of Holland), has elected Dr. Chas. Warren Hunt, Secretary Emeritus of the Society, as an Honorary Member, and has invited the Society to send a delegate to the celebration of its Seventy-fifth Anniversary to be held September 8th, 1922, at The Hague. President Freeman has appointed Dr. Hunt to represent the Society at the Anniversary, and he sailed for Europe on August 19th, 1922.

International Congress of Engineering

The Society has been invited by the Club de Engenharia, Rio de Janeiro, Brazil, to take part in the International Congress of Engineering which is to be held under the auspices of the Brazilian Government in connection with the opening of the Brazilian International Exposition in celebration of the first Centennial of Brazilian Independence.

An Editorial Committee from the four National Societies composed of P. H. Thomas, M. Am. Soc. M. E., *Chairman*, Ira W. McConnell, M. Am. Soc. C. E., G. W. Tower, Jr., M. Am. Inst. M. E., Maurice Coster, Fellow, Am. Inst. Elec. Engrs., and Ernest Hartford, Assoc. Am. Soc. M. E., has been appointed to arrange for and co-ordinate papers for a technical program. C. H. Crawford, M. Am. Soc. M. E., is Chairman of a Local Committee in Brazil, that is co-operating with the Editorial Committee.

Messrs. Walter Charnley, C. W. Comstock, V. L. Havens, W. G. McConnel, A. Y. Sundstrum, P. B. Easterbrooks, L. C. Heilbronner, Armando de Arruda Pereira, George Ribeiro, George Schobinger, Victor da Silva Freire, T. P. Stevenson, B. S. Thayer, Fred Lavis, and A. W. K. Billings, have been appointed by President Freeman as delegates of the Society to the International Congress.

ACTIVITIES OF LOCAL SECTIONS*

Meetings of Colorado Section

A regular meeting of the Colorado Section was held at the Metropole Hotel, Denver, Colo., on April 28th, 1922, as a joint meeting with the Colorado Section of the American Society of Mechanical Engineers; President L. D. Crain, of the Colorado Section of the American Society of Mechanical Engineers, presided; and there were present, also, about 30 members of both Sections.

The address of the evening was made by Mr. F. W. Bartlett who presented an interesting paper on "Radio", illustrating his remarks with one of the latest types of receiving apparatus. The subject was discussed freely by the members present, particularly the possibilities of the commercial side of this new industry. In addition, a radio concert was also given.

Meeting of July 15th, 1922

A regular meeting of the Colorado Section was held at the Metropole Hotel, Denver, Colo., on July 15th, 1922; President A. N. Miller in the chair; Thomas H. Olds, Secretary; and present, also, 11 members and 9 guests.

The minutes of the meetings of March 27th and April 28th, 1922, were read and approved. An omission in the minutes of the meeting of February 13th, 1922, was brought to the notice of the Section, and on motion, duly seconded, the minutes of that meeting were corrected to include the following: "The Secretary read a letter from the Parent Society requesting that consideration be given the question of the Society joining the Federated Engineering Societies. The question was put to a vote and the majority were opposed to joining the Federated Engineering Societies", and the Secretary was instructed to notify the Secretary of the Society of the omission.

On motion, duly seconded, the resignations of Messrs. A. L. Moser and J. S. Bright as members of the Section, were accepted.

The Secretary presented a letter from the Acting Secretary of the Society relative to a "dignified campaign for increased membership to the American Society of Civil Engineers". A motion that this matter be referred to a committee to canvass the membership of the Section was defeated. It was then moved, seconded, and carried, that the Section go on record as opposed to a dignified campaign for an increase in membership, as suggested, and the Secretary was instructed to inform the Secretary of the Society of this action.

The Secretary presented a financial report for 1921-1922, and Messrs. Bishop and Rose were named to audit the account and report at the next regular meeting of the Section.

President A. N. Miller presented an interesting paper on "Coal and Water Gas Manufacture and Distribution", in which he discussed the various steps in the manufacture of gas and the presence and utilization of numerous by-products.

J. Waldo Smith, M. Am. Soc. C. E., formerly Chief Engineer of the Board of Water Supply of New York City, who was in Denver as a member of the

* For list of Local Sections, Officers, etc., see p. 559.

Board of Consulting Engineers for the Moffat Tunnel Commission, was introduced by President Miller and addressed the meeting briefly on the "present multiplicity of administrative bodies in connection with public works and the impediment that the attendant 'red tape' usually offered to the rapid construction of such works".

J. Vipond Davies, M. Am. Soc. C. E., President of United Engineering Society, who was also in Denver as a member of the Board of Consulting Engineers for the Moffat Tunnel Commission, was next introduced, and discussed the affairs of the Federated American Engineering Societies and Engineering Foundation, outlining the origin, growth, and present status of these organizations. He also spoke of the difficulty in securing large attendance at meetings of Local Sections and outlined the proposed program of the New York Section for the coming year.

D. W. Brunton, Chairman of the Board of Consulting Engineers for the Moffat Tunnel Commission, spoke briefly of the Moffat Tunnel, and related some of the amusing and interesting experiences in connection with his work in the examination of patents during the World War.

H. S. Sands, President of the Colorado State Board of Engineer Examiners, addressed the meeting on the subject of the Engineering Library which it is proposed to purchase with funds accumulated from the payment of license fees, and stated that the Librarian of the Engineering Societies Library had promised to come to Denver and assist in the selection of books for the proposed Engineering Library which will probably be housed in the Denver Public Library.

The following officers were elected for the ensuing year: President, Thomas H. Olds; Vice-President, I. C. Crawford; and Secretary-Treasurer, R. I. Meeker.

Meetings of Duluth Section

A regular meeting of the Duluth Section was called to order at 12:15 P. M., June 19th, 1922; President W. H. Hoyt in the chair; W. G. Zimmermann, Secretary; and present, also, 20 members and 1 guest.

The minutes of the Annual Meeting, held on May 15th, 1922, were read and approved.

President Hoyt announced the appointment of the following Committees for the coming year: Entertainment: Messrs. Dickerson, Pickles, Kelly, and Stack; Publicity: Messrs. Hawley, McCool, and Ash; Auditing: Messrs. Taylor and Reed; Papers: Messrs. Darling, Dresser, and Lawrie; and Library: Messrs. Hutchinson, Ayres, and Christie.

The Secretary presented letters from Alfred D. Flinn, M. Am. Soc. C. E., Secretary of Engineering Foundation, relative to his proposed visit to Duluth, and on motion, duly seconded, President Hoyt appointed a committee of three, consisting of Messrs. Christie, Stack, and Marks, to make arrangements for a joint dinner and meeting on July 29th, 1922, of the engineers in Duluth and on the Range, and the Secretary was instructed to write to Mr. Flinn to that effect. A letter was also read from Mr. W. G. Swart, General Manager of the Mesabi Iron Company, at Babbitt, Minn., relative to Mr. Flinn's visit,

and the Secretary was instructed to invite Mr. Swart and others from Babbitt to attend the proposed meeting in Duluth.

A letter was presented from Acting Secretary Chandler of the Society relative to the suggestion by President Freeman in regard to a dignified campaign for an increased membership in the Society.

A report of the Committee on the Standardization of Map Scales was presented by Maj. Edwin H. Marks and on motion, duly seconded, the report was adopted with the decision that the matter be laid over for discussion at the next meeting of the Section.

MEETING OF JULY 17TH, 1922

A regular meeting of the Section was called to order at 12:15 P. M., on July 17th, 1922; Vice-President O. H. Dickerson in the chair; W. G. Zimmermann, Secretary; and present, also, 16 members.

The minutes of the meeting of June 19th, 1922, were read and approved.

The Secretary presented a letter from Acting Secretary Chandler in reference to the proposed Sub-Committee on Harbors and Waterways, which is to be appointed to keep the Committee on Publications advised of important local developments worthy of consideration by the Society. It was announced that the Board of Direction of the Section had forwarded the name of Mr. J. H. Darling as a prospective member for the proposed Sub-Committee.

The Secretary also called attention to a letter from Acting Secretary Chandler relative to discussion on the paper "Locomotive Loadings for Railway Bridges" by D. B. Steinman, M. Am. Soc. C. E., which is to be presented at the meeting of the Society on September 6th, 1922. Mr. Chandler requested that the Section take part in the discussion, and the Chairman urged the members interested in the subject to do so.

Mr. Frank Hutchinson reported for the Library Committee that arrangements could be made with the Public Library of the City of Duluth to have the set of *Transactions* offered by the Society to Local Sections catalogued and placed on file therein for reference. After discussion of the subject, on motion, duly seconded, the Secretary was instructed to request the Society to reserve a set of *Transactions* for the Section, until it could be determined whether the Section or the City of Duluth would pay for the binding.

The report of the Committee on Standardization of Map Scales was again presented by the Chairman, Maj. Edwin H. Marks, and after a short discussion, on motion, duly seconded, the resolution contained in the report was adopted, and the Secretary was instructed to forward the same to the Society and also to all Local Sections and to Director Anson Marston.

Resolution of Illinois Section in re Joining Federation*

The following resolution relating to the question of the Society joining the Federated American Engineering Societies was adopted at the meeting of the Illinois Section held March 24th, 1922:

"*Whereas,* The Board of Direction, Am. Soc. C. E., has asked local sections for an expression as to the advisability of the Society becoming a member of

* This resolution supplements the summary published in May, 1922, *Proceedings*, p. 378.

the Federation of Engineering Societies; and has not submitted any information regarding financial and other considerations that must be known in order for this section to intelligently pass upon the subject; and

"*Whereas,* A majority of the Society voted negatively on the question of joining the Federated American Engineering Societies a few months ago and also in view of the present unsatisfactory financial condition of our own Society which tends to restrict its activities, therefore

"*Resolved:* The Board of Direction be requested to fully advise the membership of our Society regarding the past and prospective activities, membership, resources and expenditures of the Federated American Engineering Societies, the expense attendant upon membership in the Federation, and whether it is likely the expenses will be increased; also whether, in view of the present financial condition of our Society, the expense of membership in the Federation can be borne; also to what extent, if any, it will be necessary to curtail the proper and desired activities of our Society if it joins the Federation and further

"*Resolved:* That we believe fully in the advantage of co-operative effort on the part of professional engineering societies in making the profession of engineering of greater service and increasing its prestige, and are in sympathy with the work of the Federated American Engineering Societies in such co-operative efforts as will advance the standing and usefulness of this Society and increase the welfare of its members, in so far as this can be brought about without lessening the functions and activities of this Society which fall within its own proper sphere of individual initiative and activity, and further

"*Resolved:* Pending further action by the entire membership of the Society, based upon a fuller knowledge of the issues involved, it seems advisable that the Board refrain from committing our Society in this matter and that no commitment be made by the Board except as based upon the results of the vote of the Society's entire membership."

New Officers for Kansas State Section

President L. E. Conrad of the Kansas State Section, has declared the election of Con M. Buck, M. Am. Soc. C. E., as Vice-President of the Section.

Sacramento Section Organizes

The Sacramento Section has recently been organized with an approximate membership of 53. Officers have been elected for the ensuing year, as follows: President, Albert Givan; First Vice-President, Harry A. Armstrong; Second Vice-President, H. E. Warrington; Secretary, Joseph W. Gross; Treasurer, H. A. Alderson; and Member of the Board of Directors, Frederick C. Scobey.

Fall Meeting of Texas Section

Announcement has been received from Secretary E. N. Noyes that the Fall Meeting of the Texas Section will be held at San Antonio, Tex., on October 20th and 21st, 1922.

ANNOUNCEMENTS

The Reading Room of the Society is open from 9 A. M. to 6 P. M., and from 7 P. M. to 10 P. M., every day, except Sundays, New Year's Day, Washington's Birthday, Memorial Day, Fourth of July, Labor Day, Thanksgiving Day, and Christmas Day; during July and August, it is closed at 6 P. M.

FUTURE MEETINGS

October 4th, 1922.—8 P. M.—A regular monthly business meeting will be held, at which two papers will be presented for discussion, as follows: "Experiments with Models of the Gilboa Dam and Spillway", by R. W. Gausmann and C. M. Madden, Associate Members, Am. Soc. C. E.; and "The Engineering Geology of the Catskill Water Supply", by Charles P. Berkey, Esq., and James F. Sanborn, M. Am. Soc. C. E.

These papers are printed in this number of *Proceedings.*

FALL MEETING OF THE SOCIETY AT SAN FRANCISCO, CALIF., OCTOBER 4th-9th, 1922.

October 4th, 1922.—10 A. M. and 8 P. M.—Symposium on The Water Power Problem.

October 4th.—2 P. M.—Local excursions.

October 5th.—10 A. M.—Continuation of Symposium on The Water Power Problem.

October 5th.—2 P. M.—Local excursions.

October 5th.—6:30 P. M.—Dinner and Smoker.

October 6th to 9th.—Excursion to Don Pedro, Hetch Hetchy, and Yosemite Valley.

All excursions and social functions are in the hands of the following Local Committee on Arrangements:

A. H. Markwart, *Chairman,*
H. D. Dewell, Thomas H. Means,
Ely C. Hutchinson, F. H. Tibbetts.

LOCAL SECTIONS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Section (Constitution Approved by Board, 1905).

Thomas H. Means, President; H. D. Dewell, Secretary-Treasurer, 503 Market Street, San Francisco, Calif.

Colorado Section (Constitution Approved by Board, 1909).

Thos. H. Olds, President; R. I. Meeker, Secretary-Treasurer, 4100 Zenobia Street, Denver, Colo.

Atlanta Section (Constitution Approved by Board, 1912).

William C. Spiker, President; Frederick H. McDonald, Secretary-Treasurer, 1530 Healy Building, Atlanta, Ga.

Baltimore Section (Constitution Approved by Board, 1914).

Ezra B. Whitman, President; George S. Robertson, Sr., Secretary-Treasurer, 1628 Linden Avenue, Baltimore, Md.

Buffalo Section (Constitution Approved by Board, 1921).

Walter McCulloh, President; John H. Feigel, Secretary-Treasurer, 492 Minnesota Ave., Buffalo, N. Y.

Central Ohio Section (Constitution Approved by Board, 1921).

Frank W. Jennings, President; H. F. Schryver, Secretary, 405 New York Central Building, Columbus, Ohio.

Cincinnati Section (Constitution Approved by Board, 1920).

Edgar Dow Gilman, President; Alphonse M. Westenhoff, Secretary, 709 Gwynne Building, Cincinnati, Ohio.

Cleveland Section (Constitution Approved by Board, 1915).

A. V. Ruggles, President; George H. Tinker, Secretary-Treasurer, 516 Columbia Building, Cleveland, Ohio.

Connecticut Section (Constitution Approved by Board, 1919).

Harold W. Griswold, President; Clarence M. Blair, Secretary-Treasurer, 785 Edgewood Avenue, New Haven, Conn.

Dayton Section (Constitution Approved by Board, 1922).

Charles H. Paul, President; K. C. Grant, Secretary-Treasurer, Winters Bank Building, Dayton, Ohio.

Detroit Section (Constitution Approved by Board, 1916).

H. H. Esselstyn, President; Alex. Linn Trout, Secretary-Treasurer, 110 North Ingalls Street, Ann Arbor, Mich.

District of Columbia Section (Constitution Approved by Board, 1916).

Gratz B. Strickler, President; James H. Van Wagenen, Secretary-Treasurer, 2001 Sixteenth Street, N. W., Washington, D. C.

Duluth Section (Constitution Approved by Board, 1917).

William H. Hoyt, President; Walter G. Zimmermann, Secretary, 203 Wolvin Building, Duluth, Minn.

Illinois Section (Constitution Approved by Board, 1916).

A. J. Hammond, President; W. D. Gerber, Secretary-Treasurer, 913 Chamber of Commerce, Chicago, Ill.

Iowa Section (Constitution Approved by Board, 1920).

————, President; R. W. Crum, Secretary, Care, Iowa State Highway Commission, Ames, Iowa.

Kansas City (Mo.) Section (Constitution Approved by Board, 1921).

John V. Hanna, President; Henry C. Tammen, Secretary-Treasurer, 1012 Baltimore Avenue, Kansas City, Mo.

Kansas Section (Constitution Approved by Board, 1920).

L. E. Conrad, President; F. W. Epps, Secretary-Treasurer, State Highway Comm., Topeka, Kans.

Lehigh Valley Section (Constitution Approved by Board, 1922).

George H. Blakeley, President; M. O. Fuller, Secretary-Treasurer, 732 Avenue H, Bethlehem, Pa.

Los Angeles Section (Constitution Approved by Board, 1913).

Ralph J. Reed, President; Floyd G. Dessery, Secretary, 618 Central Building, Los Angeles, Calif.

Louisiana Section (Constitution Approved by Board, 1914).

Donald Derickson, President; F. A. Muth, Secretary, 224 Custom House Building, New Orleans, La.

Nashville Section (Constitution Approved by Board, 1921).

B. H. Klyce, President; L. C. Anderson, Secretary-Treasurer, Bridge Building, Nashville, Tenn.

Nebraska Section (Constitution Approved by Board, 1917).

William Grant, President; Homer V. Knouse, Secretary-Treasurer, 200 City Hall, Omaha, Nebr.

New York Section (Constitution Approved by Board, 1920).

J. Vipond Davies, President; Harold M. Lewis, Secretary, 130 East 22d Street, New York City.

Northeastern Section (Constitution Approved by Board, 1921).

Frank B. Sanborn, Chairman; Charles W. Banks, Secretary-Treasurer, 715 Tremont Temple, Boston, Mass.

Northwestern Section (Constitution Approved by Board, 1914).

W. T. Walker, President; Paul C. Gauger, Secretary, 300 Endicott Building, St. Paul, Minn.

Oklahoma Section (Constitution Approved by Board, 1920).

Max L. Cunningham, President; R. E. Brownell, Secretary-Treasurer, 402 First National Bank Building, Oklahoma, Okla.

Philadelphia Section (Constitution Approved by Board, 1913).

William Easby, Jr., President; Charles H. Stevens, Secretary-Treasurer, 5918 North Park Avenue, Philadelphia, Pa.

Pittsburgh Section (Constitution Approved by Board, 1918).

J. N. Chester, President; Nathan Schein, Secretary-Treasurer, 1510 Carson Street, Pittsburgh, Pa.

Portland (Ore.) Section (Constitution Approved by Board, 1913).

F. M. Randlett, President; C. P. Keyser, Secretary, 318 City Hall, Portland, Ore.

Providence (R. I.) Section (Constitution Approved by Board, 1920).

Sydney Wilmot, Chairman; Robert L. Bowen, Secretary-Treasurer, 26 Sycamore Street, Providence, R. I.

Sacramento Section (Constitution Approved by Board, 1922).

Albert Givan, President; Joseph W. Gross, Secretary, Forum Building, Sacramento, Calif.

St. Louis Section (Constitution Approved by Board, 1914).

E. B. Fay, President; William C. E. Becker, Secretary-Treasurer, 426 City Hall, St. Louis, Mo.

San Diego Section (Constitution Approved by Board, 1915).

P. R. Watson, President; J. Y. Jewett, Secretary-Treasurer, Administration Building, Balboa Park, San Diego, Calif.

Seattle Section (Constitution Approved by Board, 1913).

F. F. Sinks, President; Frank H. Fowler, Secretary-Treasurer, 1319 L. C. Smith Building, Seattle, Wash.

Spokane Section (Constitution Approved by Board, 1914).

C. A. Burnette, President; Charles E. Davis, Secretary-Treasurer, 401 City Hall, Spokane, Wash.

Texas Section (Constitution Approved by Board, 1913).

E. B. Cushing, President; E. N. Noyes, Secretary-Treasurer, 1107 Dallas County Bank Building, Dallas, Tex.

Toledo Section (Constitution Approved by Board, 1922).

M. J. Riggs, President; George N. Schoonmaker, Secretary-Treasurer, 716 Stickney Avenue, Toledo, Ohio.

Utah Section (Constitution Approved by Board, 1916).

B. W. Matteson, President; H. S. Kleinschmidt, Secretary-Treasurer, 222 Felt Building, Salt Lake City, Utah.

Virginia Section (Constitution Approved by Board, 1922).

J. C. Carpenter, President; James F. MacTier, Secretary-Treasurer, 1312 Maple Avenue, Roanoke, Va.

STUDENT CHAPTERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS*

Stanford University.

R. I. Hill, President; John H. Colton, Corresponding Secretary, Box 121, Stanford, Calif.

Alabama Polytechnic Institute.

R. O. Davis, President; A. R. Harvey, Jr., Secretary, Box 661, Auburn, Ala.

Braune Civil Engineering Society (University of Cincinnati).

John W. Guilday, President; J. G. Appleton, Secretary, University of Cincinnati, Cincinnati, Ohio.

Bucknell University.

Ralph F. Hartz, President; Donald A. Davis, Secretary, Bucknell University, Lewisburg, Pa.

California Institute of Technology.

W. M. Taggart, President; Douglas A. Stromsoe, Secretary, California Institute of Technology, Pasadena, Calif.

Carnegie Institute of Technology.

H. T. Ward, President; J. K. Elliott, Secretary, Carnegie Institute of Technology, Pittsburgh, Pa.

Clemson Agricultural and Mechanical College of South Carolina.

J. H. Baumann, President; W. J. Stribling, Secretary, Clemson Agricultural and Mechanical College of South Carolina, Clemson College, S. C.

Cornell University.

Felix Spurney, President; Matthew J. Grogan, Secretary, Lincoln Hall, Cornell University, Ithaca, N. Y.

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* By a recent ruling of the Board of Direction, the minimum membership of a Student Chapter has been fixed at 12 instead of 20.

Drexel Institute.

W. J. Carroll, Chairman; Paul J. Tritschler, Secretary-Treasurer, Drexel Institute, Philadelphia, Pa.

Georgia School of Technology.

F. H. Harrison, President; C. M. Kennedy, Jr., Secretary, 91 West North Avenue, Atlanta, Ga.

Iowa State College.

Raymond L. Whannel, President; C. La Verne Day, Secretary, Iowa State College, Ames, Iowa.

Johns Hopkins University.

W. A. Randall, President; I. M. Zeskind, Secretary, Johns Hopkins University, Baltimore, Md.

Lafayette College.

Douglas M. Brown, President; Ivan C. Blickenstaff, Secretary, Lafayette College, Easton, Pa.

Lehigh University.

John N. Marshall, President; George R. Swinton, Lehigh University, Bethlehem, Pa.

Massachusetts Institute of Technology.

George Eric Barnes, President; Ralph Rutherford Dresel, Secretary, 53 Brook Street, Brookline, Mass.

Montana State College.

Merrill J. Alquist, President; Emmett Moore, Secretary, 921 South Third Avenue, Bozeman, Mont.

New York University.

George H. Martin, President; Abram J. Jacobs, Secretary, 302 Gould Hall, New York University, New York City.

North Carolina State College of Agriculture and Engineering.

H. I. Ivey, Secretary, North Carolina State College, Raleigh, N. C.

Norwich University.

J. H. Kane, President; Allen J. Hamilton, Secretary, Norwich University, Northfield, Vt.

Ohio State University.

J. H. Jefferson, President; R. G. Glass, Secretary, 98 Fourteenth Avenue, Columbus, Ohio.

Oregon State Agricultural College.

Richard D. Slater, President; Wilbur H. Welch, Secretary, Oregon State Agricultural College, Corvallis, Ore.

Pennsylvania State College.

Arthur H. McFadden, President; Ralph R. Dobelbower, Secretary, Pennsylvania State College, State College, Pa.

Polytechnic Institute of Brooklyn.

W. C. Hanning, President; S. Lordi, Secretary, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.

Purdue University.

R. O. Edwards, President; W. C. Mason, Secretary-Treasurer, Purdue University, West Lafayette, Ind.

Rensselaer Polytechnic Institute.

R. T. Carlson, President; G. C. Stephens, Secretary, 3 Walnut Grove Place, Troy, N. Y.

Rose Polytechnic Institute.

Robert Cash, President; F. Ray Martin, Secretary-Treasurer, Rose Polytechnic Institute, Terre Haute, Ind.

Rutgers College.

L. C. Kuhl, Jr., President; A. C. Ely, Secretary, 105 Winants Hall, Rutgers College, New Brunswick, N. J.

Stadia Club (University of Oklahoma).

Lester W. Ellis, President; Edward W. Mars, Secretary, University of Oklahoma, 229 W. Buffy, Norman, Okla.

State University of Iowa.

James Fred Phillips, President; Louis E. Baggs, Secretary, State University of Iowa, Iowa City, Iowa.

Swarthmore College.

Frank Lemke, President; H. Chandlee Turner, Jr., Secretary, Swarthmore College, Swarthmore, Pa.

Syracuse University.

Arthur V. Dollard, Secretary, College of Applied Science, Syracuse University, Syracuse, N. Y.

University of California.

E. F. Sutherland, President; H. E. Hedger, Secretary, University of California, Berkeley, Calif.

University of Colorado.

Glen L. Mercer, President; F. K. Whiteside, Secretary, 1205 Thirteenth Street, Boulder, Ohio.

University of Illinois.

A. L. R. Sanders, President; M. E. Jansson, Secretary, University of Illinois, Urbana, Ill.

University of Kansas.

W. W. Hoagland, President; Waldo G. Bowman, Secretary, 1106 Ohio Street, Lawrence, Kans.

University of Kentucky.

H. J. Beam, President; H. E. Glenn, Secretary-Treasurer, 348 Harrison Avenue, Lexington, Ky.

University of Maine.

Ian M. Rusk, President; Clarence B. Gould, Secretary, Sigma Phi Sigma House, University of Maine, Orono, Me.

University of Minnesota.

C. L. Swanson, President, 1716 Tyler Street, N. E., Minneapolis, Minn.

University of Missouri.

W. K. Merridith, President; Charles Ogle, Secretary, University of Missouri, Columbia, Mo.

University of Nebraska.

J. E. Applegate, President; W. H. Mengel, Secretary, University of Nebraska, Lincoln, Nebr.

University of Pennsylvania.

Charles W. Foppert, President; Fred Welchy, Secretary, University of Pennsylvania, Philadelphia, Pa.

University of Pittsburgh.

L. W. Fletcher, President; J. M. Daniels, Secretary, University of Pittsburgh, Pittsburgh, Pa.

University of Texas.

Frank Cannon, President; Claude Riney, Secretary, 1908 Wichita Street, Austin, Tex.

University of Virginia.

T. B. Kiener, Secretary, University of Virginia, University, Va.

University of Washington.

Alfred Jensen, President; H. L. Worthington, Secretary-Treasurer, 5011 Seventeenth Avenue, N. E., Seattle, Wash.

University of Wisconsin.

K. Zander, President; E. K. Loverud, Secretary-Treasurer, University of Wisconsin, Madison, Wis.

Virginia Military Institute.

Benjamin F. Parrott, President; R. G. Hunt, Secretary-Treasurer, Virginia Military Institute, Lexington, Va.

Virginia Polytechnic Institute.

W. S. Miles, President; J. Byron Herring, Secretary, Virginia Polytechnic Institute, Blacksburg, Va.

Washington University Collimation Club.

Clarence H. Miller, President; Roger C. Rowse, Secretary, 5650 Bartmer Avenue, St. Louis, Mo.

West Virginia University.

Rupert J. Snooks, President; Albert L. Kelley, Secretary-Treasurer, 660 High Street, Morgantown, W. Va.

William Cain Civil Engineering Society (University of North Carolina).

H. G. Baity, President; L. I. Lassiter, Secretary, University of North Carolina, Chapel Hill, N. C.

Worcester Polytechnic Institute.

Carl F. Meyer, President; Albert P. Hayden, Secretary, Worcester Polytechnic Institute, Worcester, Mass.

Yale University.

Harry W. Alexander, President; William H. Meyer, Secretary, Winchester Hall, Yale University, New Haven, Conn.

MEMBERSHIP

(From July 21st to August 8th, 1922)

ADDITIONS

HONORARY MEMBERS

		Date of Membership.
CHAGNAUD, LEON-JEAN. Avenue Henri-Martin, 83, Paris, France..		June 19, 1922
FITZMAURICE, *Sir* MAURICE. (Coode, Fitzmaurice, Wilson & Mitchell), Westminster Chambers, 9 Victoria St., London, S. W. 1, England		June 19, 1922

MEMBERS

HEINZ, JOHN GEORGE. Eastern Mgr., Am. Wood Pipe Co., 30 Church St., New York City		June 19, 1922
HUNTER, ALFRED HUGHLLYN. Div. Engr., Dist. No. 4, Illinois State Highway Dept., 300 South University St., Peoria, Ill		June 19, 1922
JACOBUS, ROBERT FULTON. Cons. Engr. (Francisco & Jacobus), 511 Fifth Ave., New York City		June 19, 1922
JACOBY, HURLBUT SMITH. Secy. and Chf. Engr., The H. K. Ferguson Co., 6523 Euclid Ave., Cleveland, Ohio	Assoc. M. M.	Nov. 3, 1915 June 20, 1922
MALONEY, EDGAR WILLIAM. Div. Engr., New York Water Power Investigation, 84 Pine St., New York City (Res., 316 Caton Ave., Brooklyn, N. Y.)		June 19, 1922
OAKLEY, GEORGE ISRAEL. Engr. and Supt., Guarantee Const. Co., 24 West Monroe St., Little Falls, N. Y.	Jun. Assoc. M. M.	Oct. 6, 1903 Nov. 6, 1907 June 20, 1922
SCHAUB, EUGENE. Civ. and Hydr. Engr., Logan, Utah		April 3, 1922
SINCLAIR, KARL AUGUSTUS. Chf. Engr., Warren Constr. Co., 289 East Salmon St., Portland, Ore		June 19, 1922
STEWART, RALPH WILLIAM. Chf. Deputy City Engr., 1200 Arapahoe St., Los Angeles, Calif		June 19, 1922
VOLCK, ADALBERT GEORGE. Asst. to Pres., Selznick Pictures Corporation (Res., 2011 Highland Ave.), Hollywood, Los Angeles, Calif	Jun. Assoc. M. M.	Dec. 1, 1908 Dec. 5, 1911 June 20, 1922
WILLIAMS, SIDNEY JAMES. Chf. Engr., National Safety Council, 168 North Michigan Ave., Chicago, Ill	Assoc. M. M.	Jan. 19, 1920 June 20, 1922

ASSOCIATE MEMBERS

BENNETT, FREDERICK GARDNER. Asst. Engr., Div. of Hydrology, New York Water Power Investigation, 84 Pine St., New York City (Res., 1809 Broadway, Far Rockaway, N. Y.)	June 19, 1922
CORFIELD, SHIRLEY THOMAS. Asst. Div. Engr., California Highway Comm., 603 Rowell Bldg., Fresno, Calif	June 19, 1922
GOULD, HAROLD MOFFET. Elec. Engr., Dept. of Street Railways, City of Detroit, 2191 Cadillac Ave., Detroit, Mich	April 3, 1922
THOMAS, CHARLES MITCHELL. Deck Officer, U. S. Coast and Geodetic Survey, Care, Launch *Wildcat*, 202 Burke Bldg., Seattle, Wash.	June 19, 1922
TRIOL, EDWARD KENNEDY. Junior Bridge Engr., City of Seattle, 600 County City Bldg., Seattle, Wash	June 19, 1922

JUNIORS	Date of Membership.
GREEN, FRANCIS KENNEDY. Box 129, Holden, W. Va.	April 3, 1922
HOLLER, ARTHUR FOX. Care, A. H. Cipriani, 18 Henry St., Port of Spain, Trinidad	June 19, 1922

REINSTATEMENTS

MEMBER	Date of Reinstatement.
WALDRON, ALBERT EDWIN	July 18, 1922

RESIGNATIONS

MEMBER	Date of Resignation.
GETMAN, FRANK LAWTON	July 18, 1922

DEATHS

HARRIS, ARCHIE LEE. Elected Associate Member, May 31st, 1910; died July 18th, 1922.

HARRISSON, GERARDUS. Elected Associate Member, January 13th, 1919; date of death unknown.

HOLLAND, ARTHUR FRANCIS. Elected Associate Member, October 14th, 1919; died June 22d, 1922.

JOHNSON, ALBERT LINCOLN. Elected Associate Member, September 2d, 1896; Member, December 4th, 1901; died July 21st, 1922.

MOORE, ROBERT. (*Past-President.*) Elected Member, April 5th, 1876; died July 24th, 1922.

ROSS, JAMES GEORGE. Elected Member, May 28th, 1912; date of death unknown.

SISSOEFF, SERGEI NICOLAEVITCH. Elected Member, March 13th, 1917; date of death unknown.

SMITH, FRED CHARLES. Elected Associate Member, October 29th, 1912; died June 13th, 1922.

Total Membership of the Society, August 8th, 1922

Members	**4 594**	
Associate Members	**5 254**	
Corporate Members		**9 848**
Honorary Members		**10**
Juniors		**454**
Affiliates		**169**
Fellows		**10**
Total		**10 491**

ENGINEERING SOCIETIES EMPLOYMENT SERVICE

An Engineering Societies Service Bureau was established December 1st, 1918, as an activity of Engineering Council. It was managed by a board made up of the Secretaries of the four Founder Societies, and funds for its maintenance were provided by these Societies. On January 1st, 1921, this Bureau was taken over by The Federated American Engineering Societies and was known as the Employment Service of that organization. Recently, the management of the Service has been taken over by the Founder Societies. A weekly Employment Bulletin, listing the positions available, may be seen at the office of any Secretary of a Local Section. Members of the American Society of Civil Engineers who desire to register should apply for further information, registration forms, etc., to Walter V. Brown, Manager, Engineering Societies Building, 29 West 39th Street, New York City. In order to be included in the list published in *Proceedings,* copy must be received on or before the first of each month. All communications should be addressed to Mr. Brown.

EMPLOYMENT BULLETIN

POSITIONS AVAILABLE

RESIDENT ENGINEER for real estate development company. To be in charge of sewers, water supplies, streets, etc. Must live on property. Single man preferred. Application by letter. Location, N. J. V–1372.

CIVIL ENGINEER thoroughly experienced on dam construction to act as field manager. Must have handled negro labor. Application by letter. Location, South. V–1491.

ENGINEER with good stadia and municipal survey, both field and mapping, experience. Application by letter. Location, Mass. V–1582.

COLLEGE GRADUATES (1 or 2), with two to four years' experience, for drafting work; age 26 to 28 years. Some experience in field on heavy construction and part in drafting-room in a central office. Work would consist of designing and detailing concrete and steel structures in connection with hydro-electric developments and estimating and checking same. Ability to make hurried preliminary estimates covering entire hydro-electric plant layout highly desirable. Application by letter. Salary not stated. Location, Mass. V–1655.

BRIDGE DRAFTSMEN (2). Work consists of detailing structural steelwork for bridges and buildings, reinforced concrete work for concrete slab and arch bridges, etc. Application by letter. Location, Pa. V–1690.

ENGINEER with training and experience in design, construction, and operation of a sewage treatment plant. Plant estimated to cost approximately $2 000 000. Application by letter. Salary not stated. Location, Ohio. V–1730.

ENGINEER for Chair of Civil Engineering, who has had some successful teaching experience, who is well grounded in scientific theory, and who is an administrator. Good personality. School of 1 000 students which is growing rapidly. Prefer some one who is now the head of a department in one of leading universities or who may be second man in such a department. Age between 30 and 40. Application by letter. Salary not stated. Location, Northeast. V–1760.

MAP DRAFTSMAN to plot railroad and land surveys from calculations. Experience on mining claim maps, railroad curves, or oil field layout would be satisfactory. Application by letter. Location, South America. V–1767.

STRUCTURAL STEEL DETAILER AND CHECKER AND THREE DRAFTSMEN on light structural work, stairs, balconies, etc. Application by letter. Location, Va. V–1784.

ENGINEER (C. E.) for installation of water mains in city streets. Experience in city street work desirable. Application by letter. Location, West Va. V–1857.

ESTIMATOR on structural and ornamental steel. Capable of taking full charge of estimating and securing contracts. Good opportunity to become manager of plant. Experienced men only need apply. State age, education, experience, and salary desired. Application by letter. Location, N. J. V–1868.

STRUCTURAL STEEL DESIGNER for railroad bridges. Must have this experience. Application by letter, stating age, education, and experience. Location, N. Y. V–1895.

TOPOGRAPHICAL DRAFTSMAN on water-front work. Temporary, but may be permanent if Civil Service examination is passed. Application in person. Location, New York City. V–1903.

ESTIMATOR (Building Construction) with at least 8 to 10 years' general estimating experience in structural work. Experience in New York City and vicinity much preferred. Salary not stated. Application by letter. Location, New York City. V–1912.

DESIGNERS on hydro-electric work. Civil engineer, graduate, with 5 to 7 years' experience on this class of work. Application by letter. Location, New York. V–1926.

INSTRUCTOR in Mathematics, including descriptive geometry and surveying. Appointment for three years beginning September, 1922. Recent graduate of some good engineering school preferred. Appointment by letter. Location, Syria. V–1929.

ASSISTANT PROFESSOR of Civil Engineering for next year. Should be prepared to teach surveying mechanics, hydraulics, structural design, concrete highways, etc. Salary not stated. Application by letter. Location, Pa. V–1932.

DRAFTSMAN experienced on docks, sewers, bulkheads, etc. Application in person. Location, Long Island City, N. Y. V–1935.

STRUCTURAL STEEL DRAFTSMAN AND CHECKERS (4). Permanent position. Salary not stated. Application in person. Location, Pittsburgh, Pa. V–1939.

CIVIL ENGINEER to design and construct piers, cribbing, docks, and water structures. Application by letter. Headquarters, New York City. V–1960.

ENGINEER, age 28 to 35, in Contract and Bond Department. Must have at least five years' active experience in construction work; good personality, and ability to talk convincingly. Must travel, so prefer single man. Not a high salaried position at start, but opportunity for advancement is good. Application by letter, giving complete data, including salary received in each position, and references. Interview can be arranged in any large city. Headquarters, Conn. V–1963.

GRADUATE ENGINEER, age not more than 35, to act as Instructor in Descriptive Geometry. Should have not less than three years' experience as mechanical draftsman with some reputable manufacturing concern. Application by letter. Location, Georgia. V–1975.

ESTIMATOR DRAFTSMAN, capable of taking off quantities and detailing ornamental stone-work. Some experience on construction work. Application in person. Location, New York. V–1979.

GENERAL SUPERINTENDENT of Construction on a 10-story flat slab reinforced concrete job, in Philadelphia, Pa. Must have this experience. Application by letter. Salary not stated. V–1994.

ESTIMATOR on reinforced concrete arches, etc., with 4 to 5 years' experience in this line. Application in person. Location, New York City. V–1997.

STRUCTURAL STEEL DETAILER experienced in shop detailing. Application in person. Location, New York City. V–2000.

SUPERINTENDENT of Construction. Application by letter. Location, Pa. V–2004.

EXPERIENCED CHECKERS (2) on structural steelwork. Must have had experience on buildings. Application in person. Location, New York City. V–2020.

DRAFTSMEN (2) on hydro-electric power plants. Civil engineer graduate with experience on heavy reinforced concrete. Application by letter. Location, New York City. V–2040.

DRAFTSMEN (2) for ships, hull, steelwork. Application in person. Salary not stated. Location, New York. V–2045.

DRAFTSMAN familiar with ships, joiners' work. Application in person. Salary not stated. Location, New York. V–2046.

INSTRUMENTMEN with railroad experience. Must have worked in Tropics and speak Spanish. Application by letter. Salary not stated. Location, Cuba. V–2051.

STRUCTURAL STEEL DETAILERS AND CHECKERS (5). Must be experienced men. Application in person. Location, New York City. V–2054.

MEN AVAILABLE

PROFESSOR IN CIVIL ENGINEERING and Head of such a Department in a high grade Engineering College desires to make a change. Graduate in Engineering, with post-graduate study in Education and Economics; twelve years' experience on large engineering works in positions of responsibility; ten years' experience in Engineering Education. Age, 40; married; health, excellent; least salary considered $4 500 per collegiate year. CE–351.

ENGINEER AND SUPERINTENDENT OF CONSTRUCTION, Assoc. M. Am. Soc. C. E.; technical graduate; age 43; desires position with engineering firm or contractor. Twenty years' varied experience in office and field as Engineer, Superintendent of Construction, and Executive, city improvements, water-works, streets and pavements, river and canal improvements, dredging, tunnels, deep foundations, steel and concrete structures, machinery, etc. Excellent record and reference. CE–352.

CONSTRUCTION ENGINEER, M. Am. Soc. C. E.; Graduate M. E., Stevens Institute of Technology; age, 36. Fifteen years' executive experience on design and construction of office buildings, steam and hydro-electric power plants, industrial plants, and large copper mining, milling, and reduction installation. Speaks Spanish and German fluently. Available immediately to go anywhere. Will subordinate initial salary to opportunity. Highest references. CE–353.

NEW BOOKS*

(From July 1st to July 31st, 1922)

The statements made in these notices are taken from the books themselves, and this Society is not responsible for them.

DONATIONS TO ENGINEERING SOCIETIES LIBRARY

STEAM TURBINES.

By William J. Goudie. Second Edition. Lond. and N. Y., Longmans, Green and Co., 1922. 804 pp., pl., diagrams, illus., 9 x 6 in., cloth. $10.00.

This book has been written primarily to suit the requirements of engineering students, but the author hopes that the methods of calculation outlined in it will be useful also to engineers engaged in the design or operation of steam turbines. The first part is devoted to detailed descriptions of commercial representatives of the various types now on the market. The second part treats of what may be termed the "technical" part of the subject, nozzles, blading, rotors, gearing, steam consumption, proportions, governing, etc. This edition has been completely rewritten and enlarged.

MATHEMATICAL THEORY OF PROBABILITIES.

By Arne Fisher. Second Edition, Enlarged. N. Y., The Macmillan Co., 1922. 289 pp., 9 x 6 in., cloth. $5.00.

The author's aim has been to treat all the modern researches on this important branch of applied mathematics from a common point of view, based on the mathematical principles laid down by Laplace, and to present a theory of probabilities, as developed in recent years, of value to the practical statistician, actuary, engineer, and biologist, as well as students of mathematics. This edition is extended to nearly twice its original size by added chapters on frequency functions and their applications. Mr. M. C. Rorty contributes an introductory note indicating some of the practical applications of the theory of probabilities to business problems.

CHEMICAL TECHNOLOGY AND ANALYSIS OF OILS, FATS AND WAXES: VOL. 2.

By J. Lewkowitsch. Sixth Edition, Revised by G. H. Warburton. Lond., Macmillan and Co., Ltd., 1922. 959 pp., illus., tab., 9 x 6 in., cloth. $14.00.

The second volume of the new edition of this popular treatise is concerned with methods of preparing, refining, and examining the natural oils, fats, and waxes, and of detecting adulterations. It is an exhaustive summary of present knowledge on its subject, containing detailed chemical and physical data on all known oils. This edition has been carefully revised.

LES COLLOÏDES.

Par J. Duclaux. (Actualités Scientifiques.) Paris, Gaüthier-Villars et Cie., 1922. 305 pp., 7 x 5 in., paper. 10 francs.

This work does not purport to be encyclopædic. It is, rather, a concise statement of chosen facts woven into a coherent account, from a single point of view, with useless details and superimposed theories avoided. Certain modifications have been made in the new edition. The author is Director of the Laboratory of the Pasteur Institute.

BELEUCHTUNG DER BAHNHÖFE UND DER BAHNHOFSHOCHBAUTEN.

Von Richard Sarre. (Handbuch der Ingenieurwissenschaften, 5. Teil, 5. Band.) Leipzig, Wilhelm Engelmann, 1922. 300 pp., illus., 10 x 7 in., cloth. 154 marks.

The primary object is to provide a discussion on the principles and systems of lighting railway stations and railway office buildings. As every existing method of lighting has been used for these purposes, however, and as the principles of artificial lighting are of general application, the book is, in reality, a concise survey of methods of illumination and of the laws governing their use.

UBER DIE FESTIGKEITSBERECHNUNG VON SCHIEBETOREN UND ÄHNLICHEN BAUWERKEN.

Von Adolf Eggenschwyler. Leipzig, H. A. Ludwig Degener, 1921. 148 pp., 9 x 6 in., paper.

This monograph discusses the problems in statics involved in the design of sliding sluice-gates, floating docks, movable weirs, and similar hydraulic structures composed of steel plates and frames. The statical problems that they present are, according to the author, midway between those of bridge building and shipbuilding, and have been much neglected. In consequence, the calculations of designers have been based on false assumptions, which have frequently led to an extravagant use of material and to lack of the necessary strength.

* Unless otherwise specified, books in this list have been donated by the publishers.

CURRENT CIVIL ENGINEERING LITERATURE

KEY TO ABBREVIATED REFERENCES TO PUBLICATIONS INDEXED*

Abbreviated References.	Publication.	Place.
Am. C. Inst	*American Concrete Institute, Proceedings* (Y.)	Detroit
A. I. E. E.	*American Institute of Electrical Engineers, Journal* (M.)	New York
A. R. E. A.	*American Railway Engineering Association, Proceedings* (Y.)	Chicago
A. S. T. M.	*American Society for Testing Materials, Proceedings* (Y.)	Philadelphia
Am. Soc. C. E.	*American Society of Civil Engineers, Proceedings* (M.)	New York
Am. Soc. Mun. Impvts.	*American Society for Municipal Improvements, Proceedings* (Y.)	New York
Am. W. W. Assoc.	*American Waterworks Association, Journal* (Bi-M.)	Baltimore
Am. Wood Prs. Assoc.	*American Wood Preservers Association, Proceedings* (Y.)	Baltimore
Ann. P. et C.	*Annales des Ponts et Chaussées* (Bi-M.)	Paris
Ann. T. P. Belg.	*Annales des Travaux Publics de Belgique* (Bi-M.)	Brussels
Assoc. Ing. Gand.	*Annales de l'Association des Ingénieurs sortis des Ecoles Spéciales de Gand* (Q.)	Ghent
Bost. Soc. C. E.	*Boston Society of Civil Engineers, Journal* (M.)	Boston
Can. Engr.	*Canadian Engineer* (W.)	Toronto
Cem. Eng.	*Cement and Engineering News* (M.)	Chicago
Cornell C. E.	*Cornell Civil Engineer* (M.)	Ithaca
Dock & Harbour	*Dock and Harbour Authority* (M.)	London
Eisenbau	*Der Eisenbau* (M.)	Leipzig
Eng.	*Engineering* (W.)	London
Eng. Club, St. L.	*Engineers Club, St. Louis, Journal* (Bi-M.)	St. Louis
Eng. & Contr.	*Engineering and Contracting* (W.)	Chicago
Eng. Inst. Can.	*Engineering Institute of Canada, Journal* (M.)	Montreal
Eng. N. R.	*Engineering News-Record* (W.)	New York
Engrs. Soc. Pa.	*Engineers' Society of Pennsylvnia, Journal* (M.)	Harrisburg
Engrs. Soc. W. Pa.	*Engineers' Society of Western Pennsylvania, Journal* (M.)	Pittsburgh
Engr.	*Engineer* (W.)	London
Engrs. & Eng.	*Engineers and Engineering, Engineers' Club of Philadelphia* (M.)	Philadelphia
Gen. Civ.	*Le Génie Civil* (W.)	Paris
Gesund. Ing.	*Gesundheits Ingenieur* (W.)	Munich
Inst. C. E.	*Institution of Civil Engineers Minutes of Proceedings* (Q.)	London
Inst. Mun. & Co. Engrs.	*Institution of Municipal and County Engineers, Journal* (W)	London
Int. Ry. Assoc.	*International Railway Association, Bulletin* (M.)	Brussels
Land. Arch.	*Landscape Architecture* (M.)	Harrisburg
Mech. Eng.	*Mechanical Engineering* (M.) *Journal of the American Society of Mechanical Engineers*	New York
Mil. Engr.	*Military Engineer* (M.)	Washington
Min. & Metal.	*Mining and Metallurgy* (M.) *American Institute of Mining Engineers*	New York
Mun. & Co. Eng.	*Municipal and County Engineering* (M.)	Indianapolis
N. E. W. W. Assoc.	*New England Water Works Association, Journal* (M.)	Boston
N. Y. R. R Club	*New York Railroad Club, Proceedings* (M.)	Brooklyn
Oest. Ing. Arch. Ver.	*Oesterreichischer Ingenieur und Architekten Verein, Zeitschrift* (W.)	Vienna
Power	*Power* (W.)	New York
Rev. Gen.	*Revue Générale des Chemins de Fer* (M.)	Paris
Ry. Age	*Railway Age* (W.)	New York
Ry. Main. Engr.	*Railway Maintenance Engineer* (M.)	Chicago
Ry. Rev.	*Railway Review* (W.)	Chicago
Schw. Bauz.	*Schweizerische Bauzeitung* (W.)	Zurich
Sci. Am.	*Scientific American* (M.)	New York
Soc. Ing. Civ. Fr.	*Société des Ingénieurs Civils de France, Mémoires et Comptes Rendus* (Q.)	Paris
Ver. deu. Ing.	*Verein deutscher Ingenieure, Zeitschrift* (W.)	Berlin
West. Ry. Club	*Western Railway Club, Proceedings* (M.)	Chicago
West. Soc. Engrs.	*Western Society of Engineers, Journal* (M.)	Chicago
Zeit. Bau.	*Zeitschrift fur Bauwesen* (Q.)	Berlin
Z. d. Bauver.	*Zentralblatt der Bauverwaltung* (Semi-Weekly)	Berlin

* Y = Yearly ; Q = Quarterly ; M = Monthly ; F = Fortnightly ; W = Weekly.

A. Applied Sciences

a. Processes of Calculation

2. Graphical and Nomographical

When Steel Beams Stretch.* P. J. Risdon. Sci. Am. July, '22.

B. Applied Mechanics

a. Mechanics of Solids (Strength of Materials)

2. Elastic Solids

Erweiterung der Clapeyronschen Gleichung.* (Expansion of the Clapeyron Equation.) Edgar Schmidt. Eisenbau. Apr., '22.

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3. Jointed Systems

Le calcul des Poutres a Diagonales Croisées.* (Calculation of Beams with Crossed Struts.) L. Descans. Gen. Civ. June 3, '22.

4. Riveted Systems

Beitrag zur Berechnung statisch unbestimmter Systeme.* (Contribution to the Calculation of Static Undetermined Systems.) P. Pasternak. Eisenbau. Mar., '22.

6. Heterogeneous Solids (Reinforced Materials)

Some Principles of the Construction of Unfired Pressure Vessels.* S. W. Miller. Mech. Eng. June, '22.

7. Pulverulent Masses (Earth Pressure)

Field Check on Formulas for Earth Pressure.* H. S. Schick. Eng. N. R. June 15, '22.

b. Hydraulics

2. Physical Hydraulics

Ueber die Bewegung des Wassers in künstlichen und natürlichen Gerinnen.* (The Motion of Water in Artificial and Natural Channels.) Josef Putzinger. Oest. Ing. Arch. Ver. Apr. 28, '22.

3. Industrial Hydraulics

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The Allen Hydrautomat.* Engr. June 16, '22.

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C. Materials of Construction and General Processes

a. Lime, Cement, Mortar, Concrete, Brick, Bitumen, Timber, etc.

The Effect of Alkali Upon Concrete. S. H. McCroy. (From *Public Roads.*) Cem. Eng. June, '22.

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Alkali Attack on Concrete Roads and Building Brick.* Irving Furlong. Eng. N. R. July 13, '22.

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e. Earthwork. Cubage. Excavating Machinery

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g. Execution of Works. Specifications

2. Of Concrete

Hardening Concrete Floors. Edward D. Boyer. Cem. Eng. June, '22.

Proper Finishing and Protection Against Rapid Drying, Important Features of Concrete Floor Construction. J. E. Freeman. (From *The Architect and Engineer.*) Eng. & Contr. June 28, '22.

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Knickung und zulässige Beanspruchung für Flusseisen bei Hochbauten.* (Flexure and Permissible Stress for Iron in Building Construction.) Dietrich Rühl. Ver. deu. Ing. Apr. 22, '22.

h. Foundations

Continuous-Mat Foundations for 22-Story Building.* Eng. N. R. July 13, '22.

k. Tunnels and Tunneling-Shields

Hydro-Electric Development Involves Unusual Tunnel Job.* H. K. Fox. Eng. N. R. July 13, '22.

D. Highways

a. Location

Design Features of Lincoln Highway "Ideal Section".* W. G. Thompson. Eng. N. R. June 15, '22.

c. Construction

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h. Vehicles. Automobiles

Results of Heavy Traffic on Pittsburg Test Road.* Eng. N. R. June 29, '22.

E. Bridges, Viaducts and Arches

b. Iron or Steel Bridges and Viaducts

Castleton Bridge Contracts Let.* Eng. N. R. June 15, '22.

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The Thrust in Skew Arches.* Daniel Royse. Mun. & Co. Eng. June, '22.

Construction of Weymouth Backwater Dam and Roadway.* F. Cornelius. Inst. Mun. & Co. Engrs. June 3, '22.

e. Centerings. Scaffolds

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h. Computations, Tests, etc.

Locomotive Loadings for Railway Bridges.* D. B. Steinman. Am. Soc. C. E. May, '22.

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Hydraulic Design of Bridge Waterways.* Ivan E. Houk. Eng. N. R. June 29, '22.

F. Inland Waters

c. Regulation of Waterways—Volume of Discharge, Freshets, Floods, Soundings

The Flood Problem in China.* H. T. Wright. Engr. June 2, '22.

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e. Diverting Dams. Locks. Lifts. Elevators. Inclined Planes

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j. River and Lake Ports, Equipment

New River-and-Rail Terminals on the Mississippi.* Eng. N. R. July 6, '22.

k. Utilization of Inland Waterways, Freight, Capacity

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G. Maritime Works

c. Vessels and Maritime Navigation. Lighthouses. Buoys. Various Signals

The Canadian-Pacific Liner *Empress of Australia.** Engr. June 23, '22.
The White Star Liner *Majestic.** Eng. July 7, '22.
La Vitesse des Navires de Commerce et l'Etat Actuel des Constructions Navales. (The Speed of Commercial Vessels and the Status of Marine Construction.) A. Poidloue. Gen. Civ. May 27, '22.

d. Roads and Outer Harbors. Dikes and Jetties. Breakwaters

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g. Dredges and Dredging. Force Pumps. Refloating and Removing Wrecks. Ice-Breakers

The Bucket Ladder Dredger.* George Anderson. Dock & Harbour June, '22.

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j. Dockyard Machinery and Shipyards. Dry Docks

The Enlargement of Deptford Dock, Sunderland.* Engr. June 16, '22.

H. Railroads. Street and Interurban Railways. Automobiles. Aeronautics

a. Railroads

1. General Articles
The Aftermath of Federal Control. James C. Davis. West. Ry. Club May 15, '22.
3. Roadbed. Construction Work. Tunnels
Aurora Track Elevation Expedites Traffic.* Ry. Age July 1, '22.
4. Track
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5. Signals and Safety Apparatus
On the Question of Locomotive Cab Signals.* Faustino Villa. Int. Ry. Assoc. May–June, '22.
British Approve Automatic Train Control. Ry. Age July 22, '22
6. Rolling Stock (Locomotives, Cars)
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7. Use of Electricity

On the Question of Electric Traction.* Ernest Gerard. Int. Ry. Assoc. May–June, '22.
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8. Stations. Engine Houses. Shops. Terminals

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9. Technical and Commercial Use

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10. Accidents.

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4. Track

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e. Automobiles

2. Internal Combustion Engine Automobiles

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f. Aeronautics

3. Aeroplanes

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I. Municipal Water-Works. Agricultural Engineering

a. General Articles

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Core-Wall Construction in Deep Trench at Wanaque Dam.* Arthur H. Pratt. Eng. N. R. July 20, '22.

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e. Distribution of Water

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J. Sewerage. Sewage and Refuse Disposal

b. Sewage Disposal. Purification

The Disposal of Sewage Screenings. William F. Morse. Mun. & Co. Eng. June, '22.

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K. Heat Engines

a. Steam Engines. Boilers

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b. Gas and Oil Engines

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L. Electricity

a. Production of Electricity

2. Magneto and Dynamo. Electric Machines

Questions Relating to Standards of Rating, with Particular Reference to Large Machines Using Class B Insulation.* F. D. Newbury. A. I. E. E. July, '22.

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b. Distribution and Transmission of Electricity

1. Power Plants

La Production et la Transmission de l'Energie Electrique aux Etats-Unis.* (The Production and Transmission of Electric Energy in the United States.) M. Henri Issarte. Ann. P. et C. Jan.–Feb., '22.

2. Long Distance Transmission of Energy

220-Kv. Transmission.* R. J. C. Wood. A. I. E. E. July, '22.

3. Distribution and Wiring of Electricity

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5. Transformers and Converters

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6. Safety of Electric Distribution Systems. Laws and Regulations

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d. Mechanical Uses of Electricity

1. Electric Motors

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2. Servomotors. Hoists. Elevators. Handling Machinery

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Recent Conclusions Pertaining to Electrical Precipitation.* Walter A. Schmidt. A. I. E. E. July, '22.

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f. Signals and Communication

Note on the Development of an Electron Tube Amplifier.* A. I. E. E. July, '22.

M. Architecture

a. Educational, Government and Scientific Buildings

Der Umbau des Alten Rathauses in Potsdam.* (Renovation of the Old Town Hall in Potsdam.) Dreves. Z. d. Bauver. May 13, '22.

b. Business and Commercial Buildings

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c. Residences. Hotels

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Kleinwohnungsbauten in Wädenswil.* (The Construction of Small Dwellings in Wädenswil.) Schw. Bauz. May 13, '22.

d. Storage Buildings

New Port Granary at Dublin.* Dock & Harbour June, '22.

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Plant Inventories Offer Field for Structural Engineer.* Francis W. Wilson. Eng. N. R. July 20, '22.

g. Other Buildings

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AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

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Vol. XLVIII. SEPTEMBER, 1922. No. 7.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

EXPERIMENTS WITH MODELS OF THE GILBOA DAM AND SPILLWAY

By R. W. Gausmann,* and C. M. Madden,† Associate Members, Am. Soc. C. E.

To Be Presented October 4th, 1922.

Synopsis

This paper presents the results of experiments made with models to determine the carrying capacity of a projected spillway channel and a satisfactory section of a stepped, overfall dam. There is also a discussion of the application of the principles of homology to the models in question.

General

The Gilboa Dam, located in Gilboa, Schoharie County, N. Y., forms the Schoharie Reservoir which is being constructed by the Board of Water Supply of New York City as a part of the Catskill System. A masonry section, approximately 1 324 ft. long, and an earth dike, about 1 000 ft. long, constitute the dam. The down-stream side of the masonry sections is to be formed of large steps, generally about 20 ft. high. The masonry part of the dam has a maximum height of 160 ft., and it is believed that this is the highest overfall dam of this section ever constructed. This part of the dam will be built of Cyclopean masonry, faced with native gray sandstone.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion on this paper will be closed with the December *Proceedings* and when finally closed, the paper, with discussion in full, will be published in *Transactions*.

* Div. Engr., New York Board of Water Supply, Allaben, N. Y.

† Asst. Engr., Reservoir Dept., Board of Water Supply, New York City, Cold Spring, N. Y.

Outline

This paper has been divided into three general headings:

1.—A brief history of the work done and the results obtained.

2.—A description of the experiments in the channel and on the section of the dam.

3.—A study of the differences in the results obtained with models of various scales.

History

The first model of the Gilboa Dam and Spillway was built to determine whether the channel, as designed and shown on the contract drawings under which the work is being done, was ample to carry an assumed maximum flow. The model, built on a scale of 1:50, indicated that the design was adequate, but it also showed that the steps in the overfall section did not break up the falling water as had been intended. Various modifications of the section were made, until one was found (Section 16), that seemed to meet all requirements.

Before accepting this section, it was thought advisable to experiment on a model of larger scale, as minute discrepancies made a considerable difference in the flow. The new model which consisted of only a part of the overfall section, was built on a scale of 1:20. Observation and careful measurement showed a dissimilarity in behavior in these two models, and, therefore, a larger model, on a scale of 1:8, was constructed and tested. The results of these tests proved that, as far as this section was concerned, the behavior of equivalent heads over models of different scale was not identical. This conclusion was further checked by conducting a series of experiments over flat-crested weirs built on three different scales. However, as all the results bore a certain degree of similarity, it was decided to continue the search for a suitable section, but on a model built on a scale of 1:20.

Blocks which later were modified to vanes, were placed on the upper steps to reduce the velocity, and many changes were made in the section, until a form was obtained that met all requirements. This was then reproduced on scales of 1:50 and 1:8. Measurements made over these three models still showed considerable discrepancy, but not as much as had been found in the models without vanes. This section, shown on Fig. 6, has been adopted for the Gilboa Dam to Elevation 1 020.

Experiments

Fig. 1 shows the location of the models, the details of the dam, and the controlling features. Various types of gauges were used to measure the head. Those used for all the later experiments may be seen in Fig. 2, which also shows models of Section 100 on scales of 1:50, 1:20, and 1:8, respectively, all under a proportionate head of 3 ft.

The device used to locate the outer and, in some cases, the inner edge of the jet has been called a "rectometer". It consists essentially of two scales running in guides that are normal to each other. To determine the amount of vacuum in various parts of the flow, a gauge was made, consisting of a

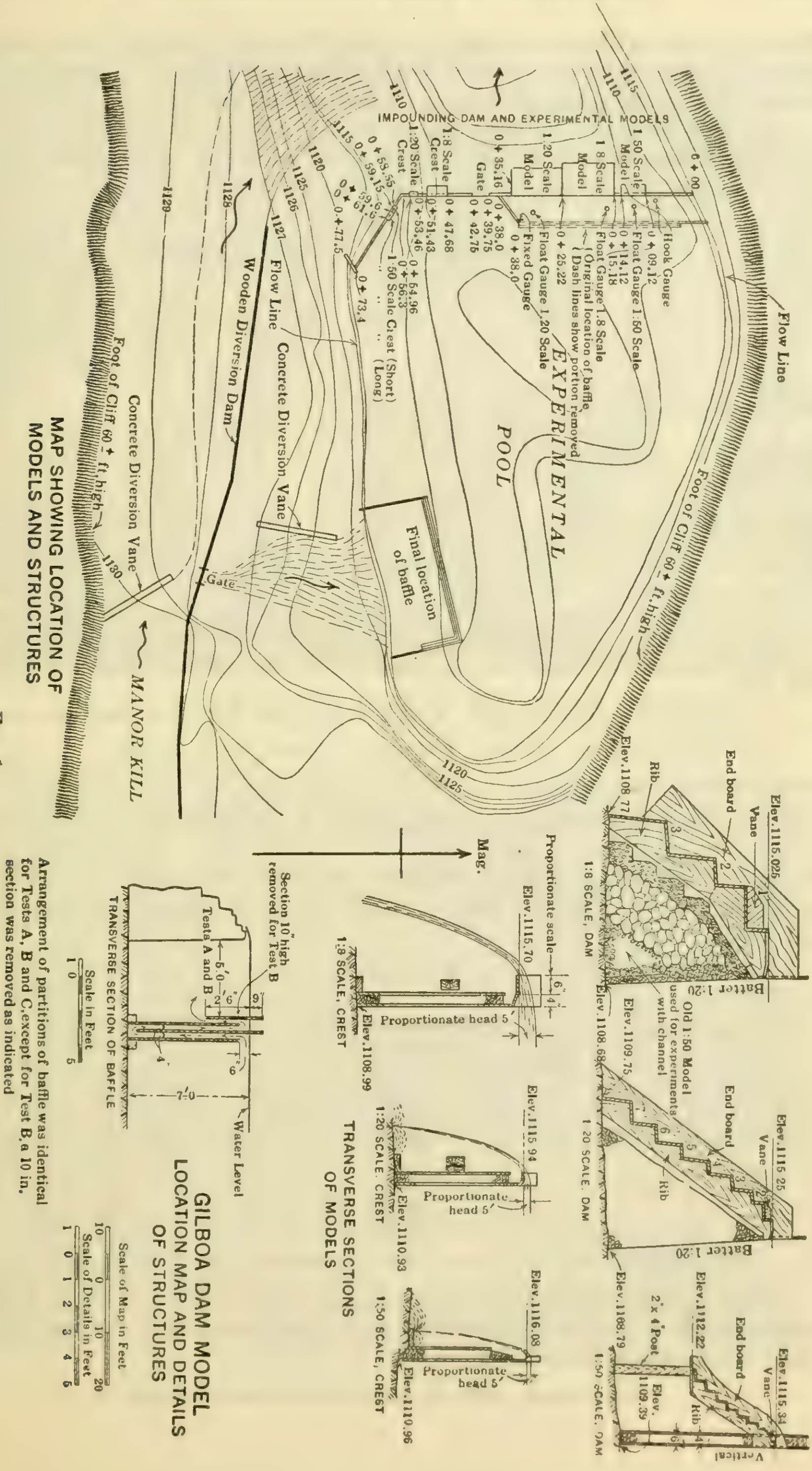

GILBOA DAM MODEL
LOCATION MAP AND DETAILS
OF STRUCTURES
MAP SHOWING LOCATION OF
MODELS AND STRUCTURES
IMPOUNDING DAM AND EXPERIMENTAL MODELS
EXPERIMENTAL
POOL
Final location
of baffle
MANOR KILL
Flow Line
Foot of Cliff 60± ft. high
Wooden Diversion Dam
Concrete Diversion Vane
Gate
Hook Gauge
Float Gauge 1:50 Scale
Float Gauge 1:8 Scale
Float Gauge 1:20 Scale
Fixed Gauge
(Original location of baffle
(Dash lines show portion removed)
1:50 Scale Model
1:8 Scale Model
1:20 Scale Model
1:8 Scale Crest
1:20 Scale Crest
1:50 Scale Crest (Short)
(Long)
Mag.
TRANSVERSE SECTIONS
OF MODELS
1:8 SCALE, DAM
1:20 SCALE, DAM
1:50 SCALE, DAM
1:8 SCALE, CREST
1:20 SCALE, CREST
1:50 SCALE, CREST
Old 1:50 Model
used for experiments
with channel
Batter 1:20
End board
Vane
Rib
2"x 4" Post
Vertical
Proportionate scale
Proportionate head 5'
Water Level
Section 10" high
removed for Test B
Tests A and B
TRANSVERSE SECTION OF BAFFLE
Scale in Feet
Scale of Map in Feet
Scale of Details in Feet
Arrangement of partitions of baffle was identical
for Tests A, B and C, except for Test B, a 10 in.
section was removed as indicated

FIG. 1.

U-tube of glass with one end open and the other end connected by a rubber tube to a piece of brass tubing of small diameter, which was inserted in the water. This gauge was graduated to read directly to 0.01 lb.

Flood Discharge and Head.—To determine reasonable heads under which to conduct these experiments, the probable maximum flow of Schoharie Creek at Gilboa must be estimated. These data are given in Table 1.

TABLE 1.

River.	Location.	Conditions.	Area of water-shed, in square miles.	Flow, in cubic feet per second.	Flow, in cubic feet per second per square mile.	Authority.*
Schoharie Creek..	Gilboa, N. Y...........	Occasional flood.	314	34 850	111	(1)
" " ..	" "	Rare flood........	314	60 730	193	(2)
" " ..	Prattsville, N. Y.......	Flood of 1903....	235	28 000	119	(3)
Pequannock........	Mecopin Intake, N. J..	" " "	62	6 000	96.8	(4)
Conemaugh	Johnstown, Pa.........	" " 1889....	48.6	10 450	215	(5)
"	" "	Occasional flood.	48.6	10 790	222	(6)
"	" "	Rare flood........	48.6	15 115	311	(7)
Calaveras..........	California..............	Flood of 1911.....	395	69 520	176	(8)
Devil's Creek......	Iowa....................	" " 1905.....	143	185 900	1 300	(9)
Great River........	Westfield, Mass........	....	350	53 170	151.9	(10)
Schoharie Creek..	Gilboa, N. Y...........	Flood of 1869.....	314	44 100	140	(11)

* (1), (2), (6), and (7), Computed from formula of the late Emil Kuichling, M. Am. Soc. C. E., found on p. 844, Report of the State Engineer on the Barge Canal, 1901.

(3), *Water Supply and Irrigation Paper 97*, 1903.

(4), Supplement to Report of the Northern New Jersey Flood Commission, March 4th, 1904.

(5), *Transactions*, Am. Soc. C. E., Vol. XXIV (1891), p. 431.

(8) and (9), Report of Arthur E. Morgan, M. Am. Soc. C. E., Chief Engineer, Miami Conservancy District, Vol. I, p. 77.

(10), "American Civil Engineers' Pocketbook", Second Edition, p. 905.

(11), Based on flood of 1903 and gauge height and resulting cross-section of the stream for the flood of 1869.

A study of Table 1 made it evident that a flood of 160 cu. ft. per sec. per sq. mile might occur. Table 2, computed from the formula,* $Q = C\ L\ (H)^{\frac{3}{2}}$, in which $C = 2.64$ and $L = 1\ 324$ ft., gives the head for various flows over the dam.

TABLE 2.

Head, in feet.	Discharge, in cubic feet per second.	Discharge, in cubic feet per second per square mile.
1	3 495	11
2	9 884	31
3	18 160	57
4	27 960	90
5	39 074	130
6	51 381	163
7	64 727	206
8	79 070	251
9	94 365	301
10	110 512	352

It was thought best to conduct experiments with heads up to 10 ft., as the maximum flood flow is indeterminate and as the vanes near the crest may cause a retardation of velocity.

* *Water Supply Paper No. 200*, U. S. Geological Survey.

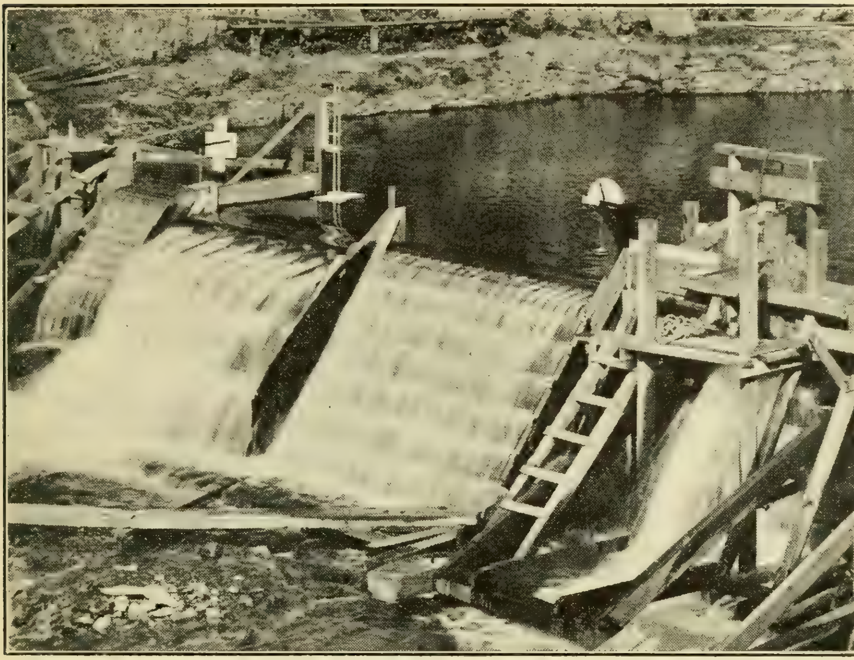


FIG. 2.—MODELS OF SECTION 100, GILBOA DAM, ON SCALES OF 1 : 50, 1 : 20, AND 1 : 8, RESPECTIVELY.

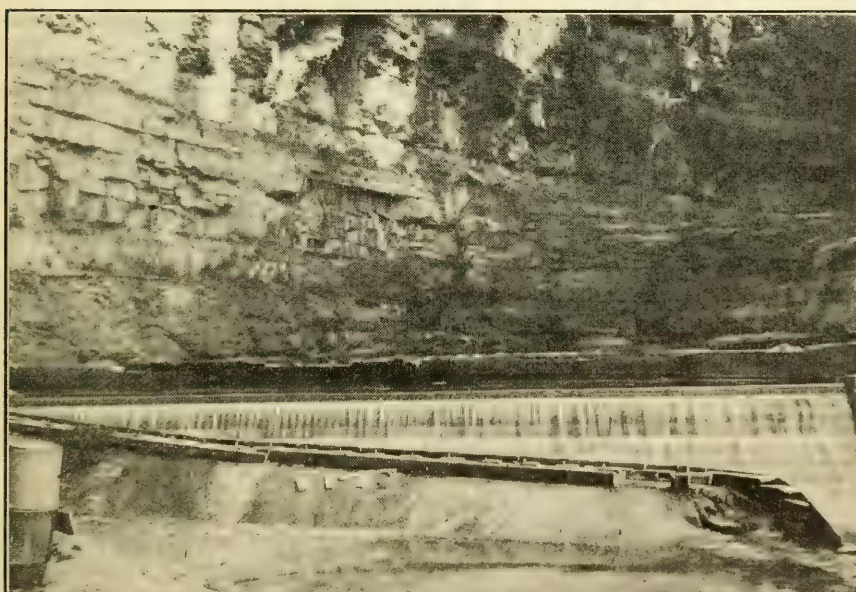


FIG. 3.—MODEL OF SECTION 16, GILBOA DAM, SHOWING EQUIVALENT HEAD OF 5 FT.

Spillway Channel.—A concrete model of the entire dam and spillway, on a scale of 1:50, was built and tested under a head equivalent to 6 ft. over the full-scale dam. Assuming a similarity in action between the model and its full-scale prototype and that the head selected would represent a maximum flood flow, it seemed to be evident that the channel was not only ample, but that its width and depth might be reduced.

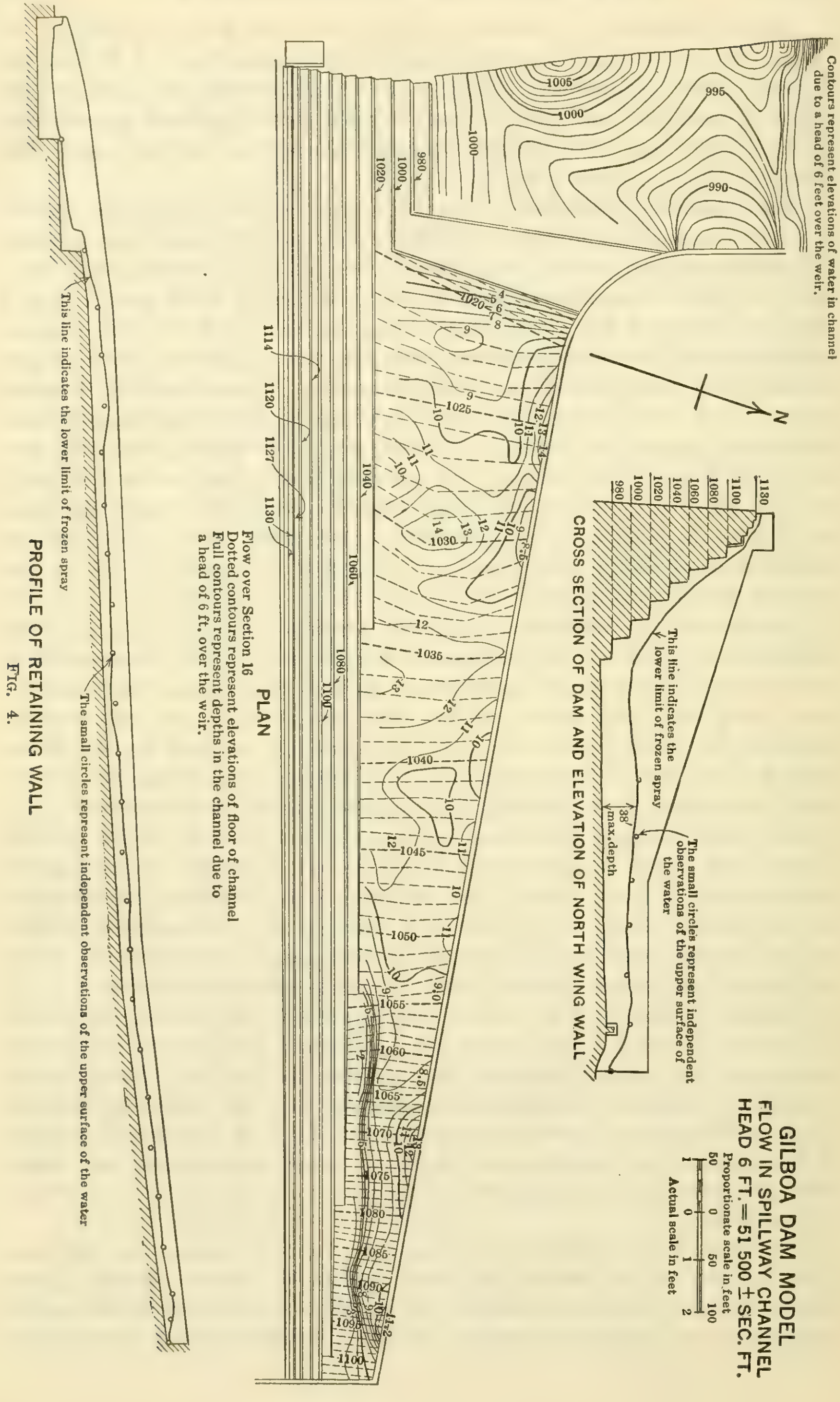
After obtaining a satisfactory overfall section on this small scale, another model of the spillway and dam, in which the width of the channel was modified, was constructed and tested. Fig. 3 shows a head of 5 ft. over this model (Section 16), under an equivalent head of 5 ft. and flow of 40 000 sec-ft. Fig. 4 shows the depths of flow in the channel due to a head of 6 ft. The contours represent depths which were approximately constant. In general, the high and the low places along the wall and in the channel, are approximately in the same place for both a 3-ft. and a 6-ft. head. This may be due to the contraction in the channel opposite the beginning of each step. The water is the same general depth throughout the channel for the same head. Thus, on the 6-ft. head, the high water at the upper end of the channel is 13 ft. deep and at the lower end, it is 14 ft., which is the greatest depth for this head. With a 3-ft. head, the maximum depth at the upper end is 5.7 ft. and at the lower end, 5.9 ft., and 6.7 ft. is the greatest depth.

As much of this work was done during freezing weather, the spray would congeal above the water line and leave a definite profile of the maximum flow. This profile is indicated by the full lines on both the retaining wall and the north wing wall and checks closely with that obtained by measurement. Although the channel has never been tried with the accepted section of the dam, it is believed that the results will be better, as the falling jet will be closer to the dam, thus increasing the available capacity of the channel.

One might conclude from these experiments that the width of the channel could be reduced 50 ft. and that the retaining wall could be reduced from its present height of from 19 to 24 ft. to a height of 17 ft. However, no changes in the dimensions shown on the contract drawing are contemplated, largely because the maximum possible flow is indeterminate, and because the action on the model will not be identical with that on its full-scale prototype.

Overfall Section.—The purpose of the experiments with the overfall section has been to develop a profile, in which a fairly equal proportion of the jet will impinge on the tread of each step, thus causing the jet to be broken up and its velocity reduced. At first, it was thought that this might be done by changing the location, width, and height of the steps. A considerable number of the combinations possible were built, on which experiments were made. Those experiments that gave fair results and some that gave poor results were measured.

In making these modifications, it was found that reasoning was comparatively useless, as the problem was too complicated. Minor changes in the section greatly influenced the path of the jet and often in the most unexpected manner, so that it became largely a matter of trying anything that did not seem to be too absurd.



PROFILE OF RETAINING WALL

FIG. 4.

In corroboration, the following is quoted from a discussion by the late George W. Rafter, M. Am. Soc. C. E.*:

"On this point the writer again calls attention to what seems to him ought to be understood by everybody, namely, that very slight change in the form of the weir often produces relatively important changes in the form of the coefficient curve. Reasoning from one coefficient curve to another is, therefore, without the slightest significance."

Generally speaking, the results with the better of all these sections showed that for low heads the break-up of the jet would be fairly good, but from 3 or 4 ft. up, too much water would impinge on one step, thus allowing the jet to accumulate and leap one, two, or three steps.

In nearly all the experimental sections, the tread slopes downward or drains. Many who examined the model, suggested that this step be sloped upward or, at least, made level. Models of both these types were constructed, and in the one with the step sloping upward, the jet rose above the level of the step and then curved downward, missing from three to four steps. A similar effect was produced with the level step, except that the jet was not projected so far.

Section 16 and, to a slightly less degree, Section 7 gave good results on the 1:50 model, but were unsatisfactory when tested on the larger scales. After many trials, it was concluded that the desired results could not be obtained with a simple stepped section, but that some other means must be used to reduce the velocity and break up the falling sheet of water.

The early experiments, along this line, consisted in placing obstructions in the form of rectangular blocks 6.0 ft. long, 3.0 ft. wide, and 4.0 ft. high, at various intervals along the tread of the first step, the long side being parallel with the edge of the step. This showed a slight improvement over sections without blocks.

Blocks were then designed, the long edge of which was at an angle of 30° with the edge of the step. The edges of these blocks were cut, so that a part was normal and the remainder parallel to the edge of the step. These blocks were tried in many arrangements. In one of these arrangements, the block was placed on the down-stream edge of the crest and particularly good results were obtained. This arrangement, however, would raise the flow line of the reservoir higher than had been planned and, in addition, the blocks would be a constant target for floating débris, ice, etc., and a combination of circumstances might readily be imagined, in which the openings between the blocks would become clogged, thus making them valueless for retarding velocity. An isolated block or series of blocks would be difficult to hold in place.

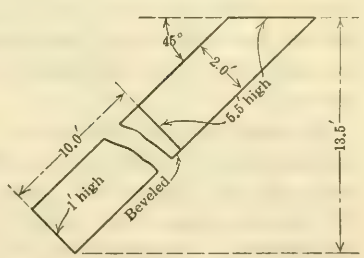


FIG. 5.

To overcome some of these troubles, the block was again placed on the first step, but was extended back to the riser, thus forming a series of vanes.

* *Transactions*, Am. Soc. C. E., Vol. XLIV (1900), p. 391.

The first experiments with these vanes were discouraging, but after many trials, a vane, shown in Fig. 5, was found, that gave better results than the blocks.

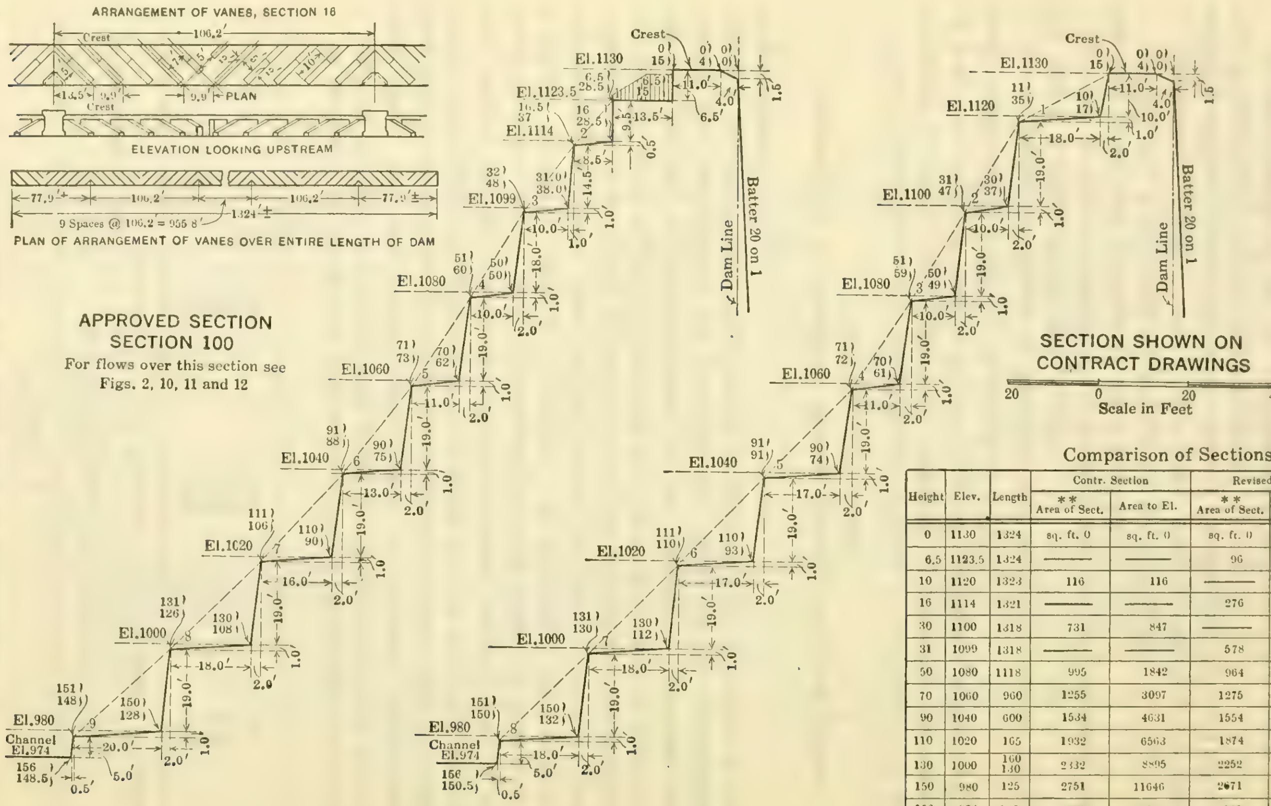
It was decided to accept the crest, first step, and vanes and to adjust the remainder of the section to them. The model at this time consisted of a wooden top down to the third step, and concrete steps below. By using boards of various widths and thicknesses, many modifications were made, until one was found that seemed to give better results than all the others. With this section as a basis, a new model was constructed, in which the risers and treads were adjustable, and experiments were conducted by starting first with the basic and then with a maximum and minimum section and determining the three most satisfactory sections. Experiments with the three sections thus obtained were then re-run and compared, and the best one was accepted. This was modified later and improved by lowering the second step 6 in., and this section was adopted to Elevation 1020.

In order that a careful analysis might be made of the varying flows over these sections, a tabular form was prepared on which zero was used to indicate that no change has been made in the section; — 1 that the tread has been dropped 1 ft., or the riser has been placed 1 ft. farther in than in the normal section; and + 1, that the tread has been raised 1 ft., or the riser placed 1 ft. farther out. An analysis was also made of the effect of varying heads over the adjusted section, by the use of symbols to represent whether the inner edge of the flow hit heavily or lightly on the steps. This tabulation made it simpler to compare the flows over the varying heads and to analyze their differences.

The foregoing tests were conducted on a 1:20 model. As a verification, a model was constructed of the full height of the dam on a scale of 1:50, and another model, on a scale of 1:8, down to the fourth step. A detailed description of the action over these models will be given subsequently, but it may be noted here, that although it was not identical, the discrepancy was not excessive.

In extending this section for the full length of the dam, with all the vanes pointing in one direction, water will be piled up against one end. It is thought that, with the higher flows, there will be a tendency for the water to pile up on Step 2, unless some means is provided for admitting air behind the jet at intervals. This might be accomplished by changing the direction of the vanes at intervals, as shown on Fig. 6. Other considerations have led to the decision of making only one change in the direction of the vanes. This change will be made at the west end of the dam opposite the gorge. One hundred and eighty-six different experiments were recorded. This includes flows over one hundred different sections.

Miscellaneous.—As experiments were conducted, tests were made to determine whether a partial vacuum was present in any of the flows. The only place it was found was in the whirl below the blocks or between the vanes. On the 1:8 model, a series of ten readings was taken on each of five different heads, the results of which are shown in Table 3.



Comparison of Sections

Height	Elev.	Length	Contr. Section: ** Area of Sect.	Contr. Section: Area to El.	Revised Section: ** Area of Sect.	Revised Section: Area to El.	Comparison with Contr. Sect.
0	1130	1324	sq. ft. 0	sq. ft. 0	sq. ft. 0	sq. ft. 0	sq. ft.
6.5	1123.5	1324	———	———	96	96	
10	1120	1323	116	116	———	———	
16	1114	1321	———	———	276	372	
30	1100	1318	731	847	———	———	
31	1099	1318	———	———	578	950	
50	1080	1118	995	1842	964	1914	+ 72
70	1060	960	1255	3097	1275	3189	+ 92
90	1040	600	1534	4631	1554	4743	+ 112
110	1020	165	1932	6563	1874	6617	+ 54
130	1000	160 130	2332	8895	2252	8869	- 26
150	980	125	2751	11646	2671	11540	- 106
156	974	130	938	12584	926	12465	- 119

**Area of section between the elevation given and the elevation next above for the designated section, thus 731 on 5th line = area of section between elev. 1100 & 1120

FIG. 6.

TABLE 3.

Head, in feet.	Negative Pressures, in Pounds per Square Inch.		
	Maximum.	Minimum.	Average of ten readings.
3	0.11	0.03	0.07
4	0.15	0.02	0.06
5	0.23	0.11	0.18
6	0.23	0.13	0.19
8.7	0.20	0.07	0.14

It seemed to be the general impression that, on the models without vanes, a negative pressure might be found under the jet from the crest to the first step. Here, the water back of the jet was at a noticeably higher elevation than that in front of it. Numerous tests, however, showed that the entrained air was at atmospheric pressure. It is thought that the following explanation may account for this. When the water first passes over the crest, it follows down the riser. As the head is increased, the water leaves the riser and forms a jet, the section of which is a parabola. As the head is further increased, the curve is extended. Now, if both ends of the jet are sealed, an air-tight compartment is left back of the jet. As this compartment is enlarged by increases of head, there is a tendency for a partial vacuum to form back of the jet, but this is counterbalanced by the atmospheric pressure outside, forcing the water up in the compartment. Thus, as the compartment is enlarged, the water level behind the jet is raised, but the atmospheric pressure is not reduced.

Dissimilarity in Action of Proportionate Flows Over Models of Different Scales

Field Observations.—The dissimilarity, referred to previously, will now be discussed in detail. Fig. 7 shows the relativity of the outer and inner edge of jets for models of Section 16, built on three different scales and tested under heads of 3, 5, and 6 ft. It may be noted that:

1.—A similar divergence of the outer edge of the jet, due to the scale of the model, is found for all three heads.

2.—On the crest, the depth of the water is less for the 1:50 model than for the 1:20 model, and greatest for the 1:8 model.

3.—On Step 2, the depth is greatest for the 1:50 model.

4.—Between Steps 3 and 5, the outer edge of the jet, for the 1:20 model, is midway between the outer edges of the jets for 1:8 and 1:50 models; this is particularly true for the 6-ft. head.

5.—The location of the jet, as defined by its inner edge, varies with the scale of the model.

At first, the discrepancy in the behavior of the 1:50 and 1:20 models was thought to be due to the location of the baffle, but nearly identical results were obtained after moving the baffle, as shown by Fig. 1. Fig. 8 gives definite proof

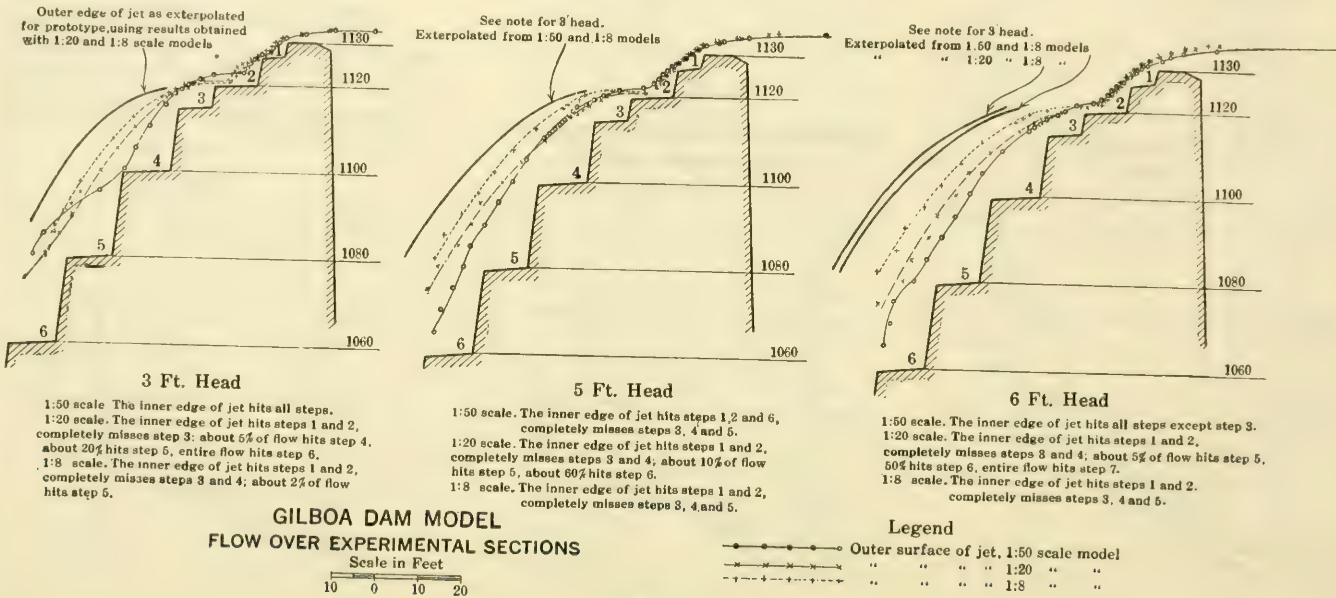

Outer edge of jet as exterpolated for prototype, using results obtained with 1:20 and 1:8 scale models
1130
1120
1100
1080
1060
3 Ft. Head
1:50 scale The inner edge of jet hits all steps.
1:20 scale. The inner edge of jet hits steps 1 and 2, completely misses step 3: about 5% of flow hits step 4, about 20% hits step 5, entire flow hits step 6.
1:8 scale. The inner edge of jet hits steps 1 and 2, completely misses steps 3 and 4; about 2% of flow hits step 5.
See note for 3' head.
Exterpolated from 1:50 and 1:8 models
5 Ft. Head
1:50 scale. The inner edge of jet hits steps 1,2 and 6, completely misses steps 3, 4 and 5.
1:20 scale. The inner edge of jet hits steps 1 and 2, completely misses steps 3 and 4; about 10% of flow hits step 5, about 60% hits step 6.
1:8 scale. The inner edge of jet hits steps 1 and 2, completely misses steps 3, 4 and 5.
See note for 3' head.
Exterpolated from 1.50 and 1:8 models
" " 1:20 " 1:8 "
6 Ft. Head
1:50 scale. The inner edge of jet hits all steps except step 3.
1:20 scale. The inner edge of jet hits steps 1 and 2, completely misses steps 3 and 4; about 5% of flow hits step 5, 50% hits step 6, entire flow hits step 7.
1:8 scale. The inner edge of jet hits steps 1 and 2. completely misses steps 3, 4 and 5.
GILBOA DAM MODEL
FLOW OVER EXPERIMENTAL SECTIONS
Scale in Feet
10 0 10 20
Legend
Outer surface of jet, 1:50 scale model
" " " " 1:20 " "
" " " " 1:8 " "

FIG. 7.

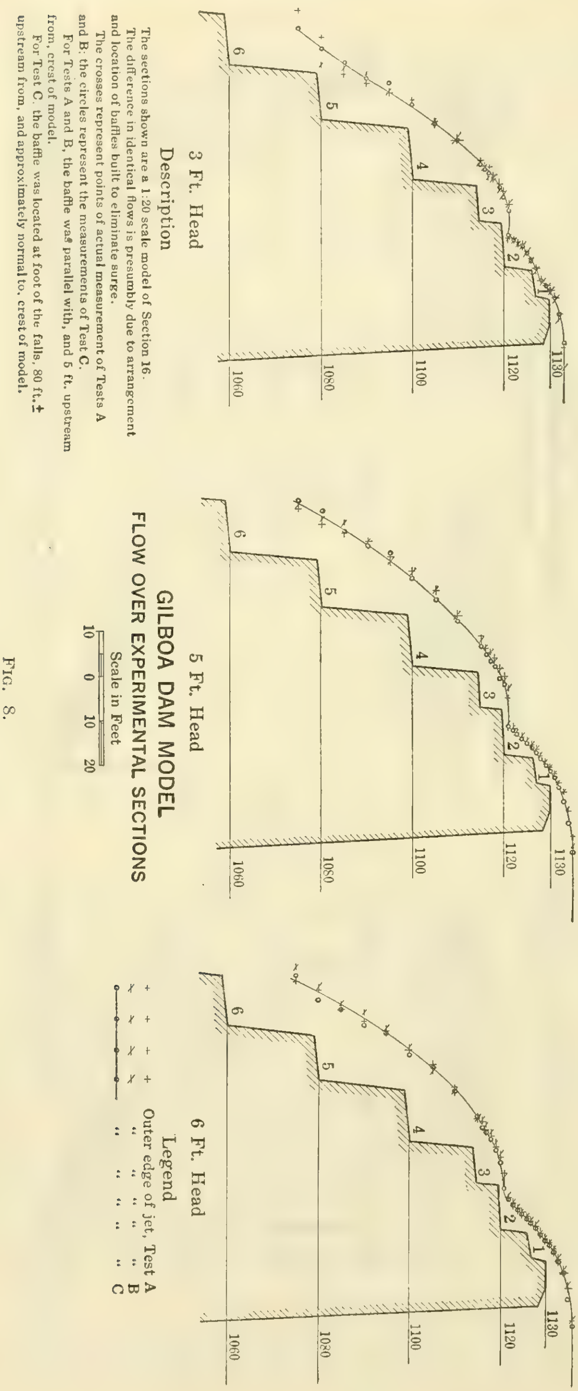

3 Ft. Head
5 Ft. Head
6 Ft. Head
6
5
4
3
2
1
1060
1080
1100
1120
1130
GILBOA DAM MODEL
FLOW OVER EXPERIMENTAL SECTIONS
Scale in Feet
10 0 10 20
Description
The sections shown are a 1:20 scale model of Section 16.
The difference in identical flows is presumbly due to arrangement and location of baffles built to eliminate surge.
The crosses represent points of actual measurement of Tests A and B; the circles represent the measurements of Test C.
For Tests A and B, the baffle was parallel with, and 5 ft. upstream from, crest of model.
For Test C, the baffle was located at foot of the falls, 80 ft.± upstream from, and approximately normal to, crest of model.
Legend
Outer edge of jet, Test A
" " " " " B
" " " " " C

FIG. 8.

of the consistency of the jet under similar conditions and of the accuracy of the measurements.

Fig. 9 shows the measurements taken on jets over the 1:50, 1:20, and 1:8 models of the accepted section, with a proportionate head of 5 ft. On the 1:20 and 1:50 models, the outer edge of the jet shown was determined by holding a straight-edge level in such a position that the outer part of the outside face of the jet just touched the straight edge. This point was then projected on the board forming the end of the model. The circles in Fig. 9 represent these points. On the 1:8 model, the points were located in a similar manner, except that it was found more practical to locate the point by eye than by the use of a straight-edge. A part of the jet hit the tread of each step on all models.

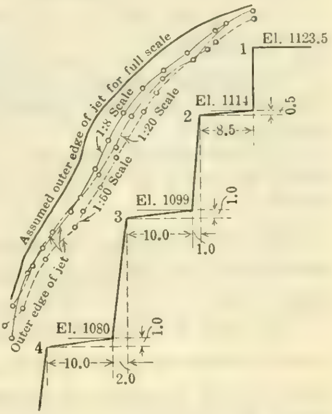


FIG. 9.

It was found by measurements in the field that the outer edge of the jet of the 1:20 model is about midway between the jets on the 1:50 and 1:8 models. From this, by interpolation, it was assumed that the outer edge of the jet may be approximately located for the full-scale dam. This assumption is checked theoretically by the fact that the force of the falling water, which projects the spray, increases as the cube of the scale ratio. Other forces, however, may materially change the location of this line. A comparison of Fig. 9 with Fig. 7 will show, that the introduction of vanes in the upper part of the section, by diminishing the velocity, has considerably reduced the dissimilarity due to scale. Figs. 10, 11, and 12 give further proof of this dissimilarity, by showing the effect of a proportionate head of 3 ft. over the crest of the accepted section on models of all three scales, the photographs being enlarged to show the models the same size.

The water passes over the vanes of the 1:50 model (Fig. 12) with no perceptible break-up. The surface of the jet is so smooth that the grain of the wood in the vanes can be readily seen through it. There is some break-up of the jet with the 1:20 model (Fig. 10), and a certain quantity of spray is cast out, as the water falls over the blocks. With the 1:8 model (Fig. 11), a large proportion of the jet is broken up into spray.

In order to test further for this dissimilarity, three flat-crested weirs, with a free overfall, were built on scales of 1:8, 1:20, and 1:50, with a proportionate length of 30 ft. Sections of these weirs are shown on Fig. 1, and the outer and inner surfaces of the jet, at the center of the weir, under heads of 3, 5, and 6 ft. as measured with the rectometer, and plotted on a proportionate scale, are shown on Fig. 13. These three jets, although following the same general line are consistently dissimilar. It will be noted in comparing the jets over the models of different scales for any head, that there is a consistent divergence in their traces. This is due to the proportionately different effects of viscosity, skin friction, and surface tension, owing

to the scale of the model. It will also be seen that this divergence is greatest for the 3-ft. head and is least for the 6-ft. head, because the proportionately different effects of viscosity, etc., are greater at low heads.

Theory of Models.—In the Century Dictionary, the word, model, is defined as:

"A detailed pattern of a thing to be made; a representation, generally in miniature of the parts, proportions, and other details to be copied in a complete production.

"A mechanical imitation or copy of an object generally on a miniature scale, designed to show its formation; hence, an exact reproduction; a facsimile."

In the following discussion, a model will be considered to be in exact geometrical similarity to its prototype, with all linear dimensions in the same scale ratio.

The late William M. Torrance, M. Am. Soc. C. E.,* takes up the design of static structures from models, and points out, that a model water tank on a scale of 1:30 was proportionately thirty times stronger than its full-scale prototype. Fig. 14 shows similar computations for a water tower, a beam, and a gravity dam, the principle being the same in all cases, namely, that the unit strength varies inversely with the scale ratio. In dynamic models, the principal causes of dissimilarity in action are: force, velocity, viscosity, and atmospheric pressure.

B. F. Groat, M. Am. Soc. C. E.,† presents the following formula for extraneous force ratio: For the proportionality of force ratio between the model and its prototype, when the tests are conducted on the same place on the earth's surface, the ratio of the densities of the two substances equals the ratio of the cube of the linear dimensions. If the same substance is used for both model and prototype, the extraneous forces are proportional to the cube of the scale ratio.

This may be illustrated by the following numerical example: Visualize a 4-ft., solid, wooden cube, weighing 56 lb. per cu. ft., and a model of the same material on a scale of 1:2. The large block will weigh 3 584 lb. and the small block, 448 lb. If the larger block falls 20 ft., its velocity will be 35.87 ft. per sec. and the time required will be 1.12 sec. The force, $\dfrac{\text{velocity} \times \text{mass‡}}{\text{time}} = 115\ 820 \pm$ ft-lb., per sec. Using the same linear scale ratio, the smaller block will fall 10 ft., and its velocity will be 25.36 ft. per sec., the time 0.789 sec., and the force 14 400 $\pm$ ft-lb. per sec. Thus, the ratio for the model and its prototype will be 1:8, or as the cube of the scale ratio.

If the smaller block is made of cast iron weighing 448 lb. per cu. ft., and the scale ratio remains the same, the weights will vary as 1:8, or as the cube of the scale ratio, and both cubes will weigh the same. If the smaller block falls 10 ft., its force will be the same as the larger block falling 20

* "Use of Models in Engineering Design", *Engineering News*, December 18th, 1913.

† *Transactions*, Am. Soc. C. E., Vol. LXXXII (1918), pp. 1181 and 1190.

‡ "Civil Engineers' Pocket Book", John C. Trautwine, 1904, p. 337.

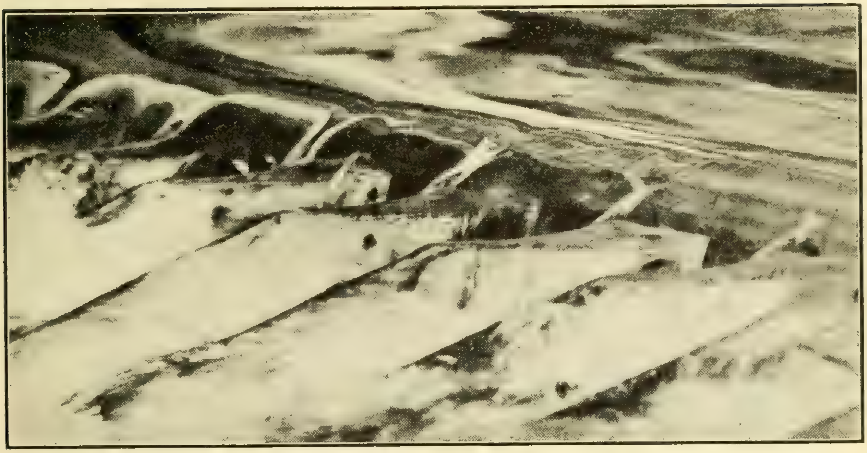


FIG. 10.—GILBOA DAM, SCALE 1 : 20, PROPORTIONATE HEAD, 3 FT.

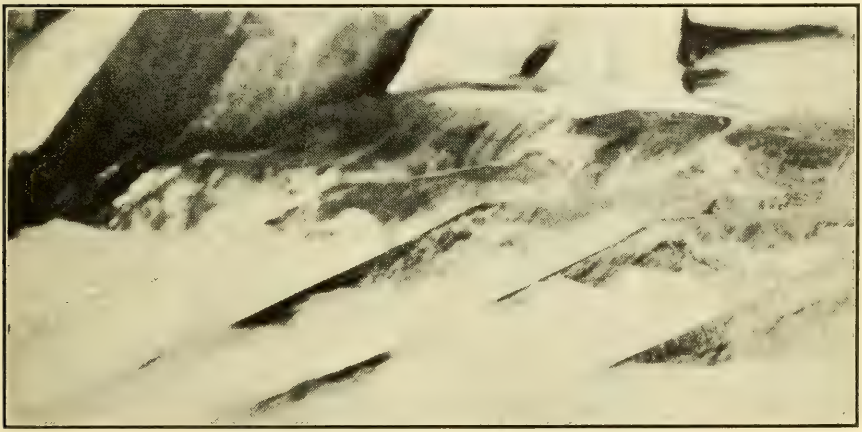


FIG. 11.—GILBOA DAM, SCALE 1 : 8, PROPORTIONATE HEAD, 3 FT.

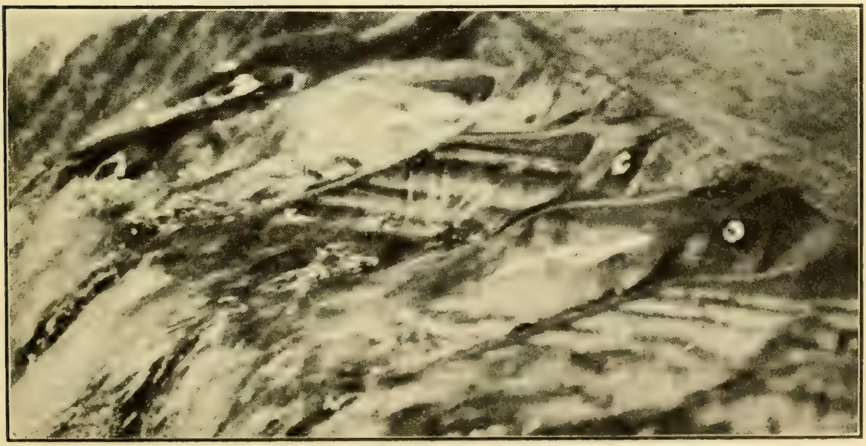


FIG. 12.—GILBOA DAM, SCALE 1 : 50, PROPORTIONATE HEAD, 3 FT.

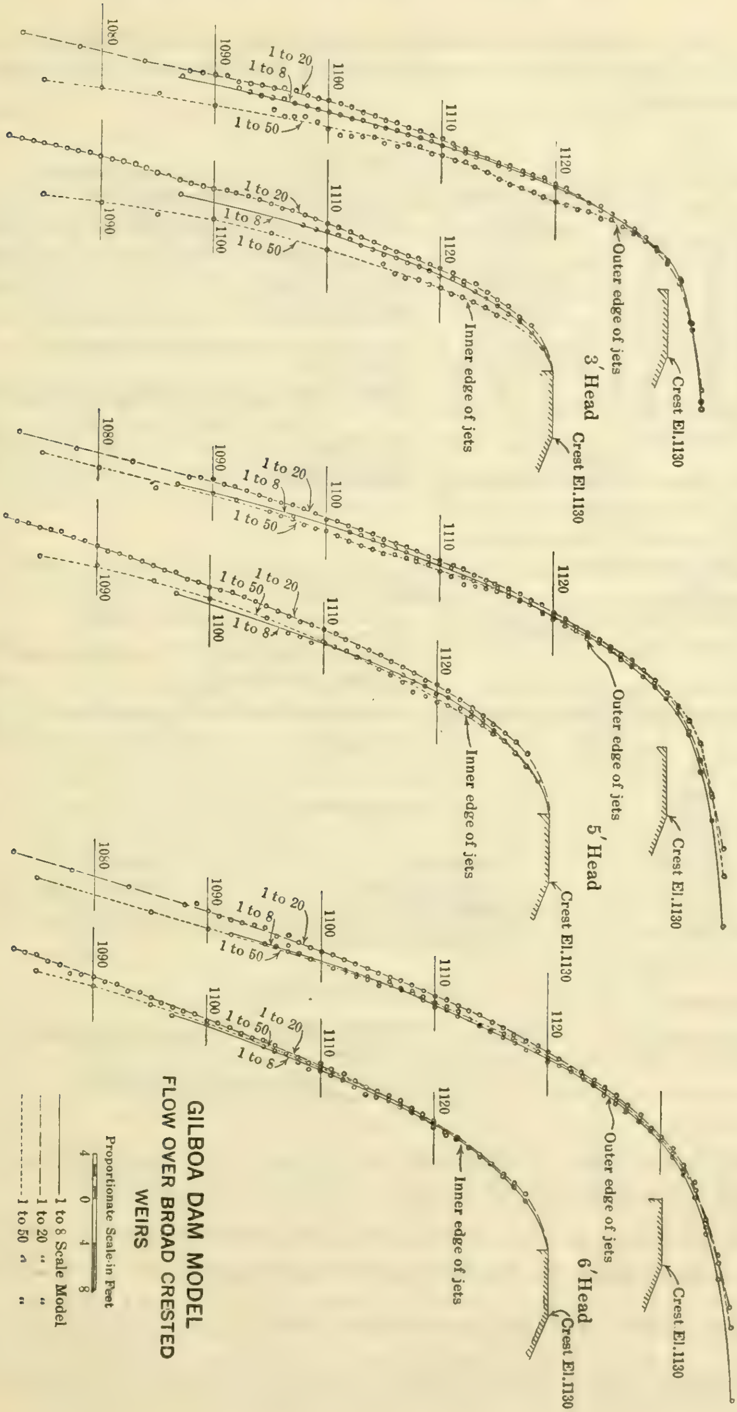
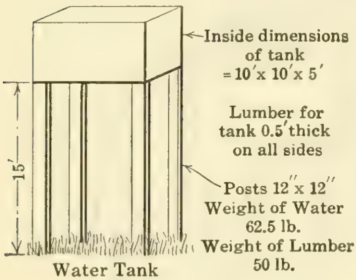

GILBOA DAM MODEL
FLOW OVER BROAD CRESTED WEIRS
3' Head
5' Head
6' Head
Outer edge of jets
Inner edge of jets
Crest El.1130
1 to 20
1 to 8
1 to 50
1080
1090
1100
1110
1120
Proportionate Scale in Feet
4 0 4 8
1 to 8 Scale Model
1 to 20 " "
1 to 50 " "

FIG. 13.

ft. Thus, if materials of different densities are used, to obtain an equal force, the scale ratio for the model and its prototype will be the cube root of the densities.



Water Tank

(1) Compute stress in lb. per sq. in. on lower end of post where it enters the ground

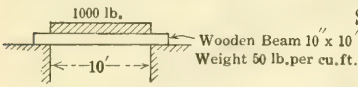
Weight of water = 10 x 10 x 5 x 62.5 =	31 250 lb.
" " tank = 0.5[(5 x 4 x 10.5) + 11^2] x 50 =	8 275 lb.
" " posts = 15 x 1 x 1 x 4 x 50	3 000 lb.
Total Weight	42 525 lb.
Weight per post	10 631.2 lb.
Weight per sq. in.	73.8 lb.

(2) Compute same data for a model built on a scale of 1:10

Weight of water 1 x 1 x 0.5 x 62.5	31.25 lb.
" " tank = 0.05[(0.5 x 4 x 1.05) + 1.1^2] x 50 =	8.275 lb.
" " posts = 1.5 x 0.1 x 0.1 x 4 x 50 =	3.00 lb.
Total Weight	42.525 lb.
Weight per post	10.631 lb.
Weight per sq. in.	7.38 lb.

Results

Weight varies as the cube of the scale ratio
Area " " " square " " " "
Strength " inversly as " " "
i.e. the unit strength of the model is ten times that of its prototype.



Simple Beam

Let W = weight of load and beam = 1344 lb.
L = length of span = 120 in.
b = width of beam = 10 in. d = depth of beam = 10 in.
s = stress in lb. per sq. in.

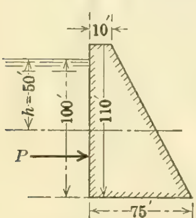
$\frac{WL}{8} = \frac{sbd^2}{6}$ s = 121 lb.

For model scale 1 to 10 W = 1.34 lb. L = 12 in. b = 1 in.

$\frac{WL}{8} = \frac{sbd^2}{6}$ d = 1 in. s = 12.1 lb.

Results

Weight varies as the cube of the scale ratio
Area " " " square " " " " "
Strength " inversly as " " "



Length 20′

Weight of Masonry 125 lb. per cu.ft.

Dam (Stability)

Full Scale	Model
$P = ahw$ = 6 250 000 lb.	$P = ahw$ = 6 250 lb.
Weight of dam = 11 687 500 lb.	Weight of dam = 11 687.5 lb.

Therefore stability against overturning is the same in the model and prototype

Dam (Pressure on Base)

$$\text{Unit Press} = \frac{P + \text{Weight of dam}}{\text{Area of base}} =$$ 11 958 lb. for full scale and 1 195.8 lb. for 1:10 model, thus the unit pressure is inversly proportional to the scale ratio

FIG. 14.

Mr. Groat* gives a theoretical discussion on the proportionality of the velocity in a model and its prototype. Briefly, it is as follows:

By the Chezy formula for the flow in channels or rivers, $v = c\sqrt{r\,s}$; let this equation stand for the flow in the model, and let $V = C\sqrt{R\,S}$ be the equation for flow in the full-size prototype. Then, $\frac{v}{V} = \frac{c\sqrt{r\,s}}{C\sqrt{R\,S}}$ will show the relation between the two flows. If the model and its surfaces are both

* *Transactions*, Am. Soc. C. E., Vol. LXXXII (1918), p. 1173.

geometrically similar to the prototype, then $\frac{c}{C} = 1$ and $\frac{s}{S} = 1$. Squaring and eliminating $\frac{v^2}{V^2} = \frac{r}{R}$; therefore, $\frac{v}{V} = \frac{\sqrt{r}}{\sqrt{R}}$; showing that the "velocities should be proportional to the square roots of the hydraulic radii, and, therefore, to the square roots of any homologous linear dimension", or to the square root of the scale ratio. It can be shown that this will apply equally well to a weir. Thus, if a model of a weir or channel is geometrically and mechanically similar to its prototype, the velocity will vary as the square root of the scale ratio. Generally speaking, it will be found difficult in the construction of practical weirs to make the ratio of the two coefficients of roughness equal unity and, consequently, $\frac{c}{C}$ will not exactly equal unity.

The velocity of the wind will vary in the same manner as other velocities, that is, as the square root of the scale ratio. A 5-mile breeze on the model, on a scale of 1:50, will be equivalent to a 35-mile wind on the full-scale prototype.

Mr. Groat* states: "This shows that cases of pure stream-line flow cannot be reproduced in models unless the sizes of the models are properly determined by Equation (19)". This equation is, $L^{\frac{3}{2}} = N(G)^{-\frac{1}{2}}$, in which L equals the scale ratio, N the ratio of the kinematical coefficients of viscosity corresponding to the coefficients of viscosity of different fluids used in the model and the prototype, and G equals the gravity ratio.

"As examples of the uses of Equation (19), when $G = 1$, it may be shown: (a) that a model air propeller in mercury at 20° cent. should be one-twenty-fifth full size for the prototype in air at 15° cent.; (b) that the scale ratio of a model water-wheel tested in mercury at 20° cent., should be about 0.22 for the prototype in water at 15° cent. * * *"

"* * *. With $G = 1$, Equation (19) shows that the model requires a different fluid from that for the prototype when both observations are made at the same place."

Thus, an overfall dam to give the same results as its prototype, should have its model tested with some liquid other than water.

Under ordinary conditions of testing, the atmospheric pressure is the same for both the model and its prototype; thus, in the prototype the atmosphere will support a column of water 33.9 ft. high. As the atmospheric pressure remains practically a constant, it will support the same height of water in a model regardless of the scale. Thus, in a model on a scale of 1:50, the atmosphere would apparently support a column of water 1 695 ft. high. Unless some means are taken to reduce this pressure, proportionately to the scale of the model, in hydraulic flows in which there is a partial vacuum, or negative pressure, the action of the model will differ from that of its prototype.

Application of the Theory of Models to the Models of the Gilboa Dam.—Probably the principal cause for the dissimilarity below the crest in models

* *Transactions*, Am. Soc. C. E., Vol. LXXXII (1918), pp. 1186 and 1187.

of various scales, is the variation in force due to the scale of the model. It has already been shown that this varies as the cube of the scale ratio. Thus, the force exerted by any part of the jet falling on the 1:8 scale model is 2.5^3, or 15.6 times greater than the force exerted by the homologous part of the jet falling on the 1:20 model, or $6.25^3 = 244.1$ times greater than on the 1:50 model. This force is largely expended in breaking up the jet and in causing the particles of the jet to be projected farther.

It is believed that this explains the difference in the action over the vanes, as shown in Figs. 10, 11, and 12. A study of these photographs will show, that, in the 1:50 model (Fig. 12), the surface of the jet passing over the vane and first step is nearly smooth. The impact is so slight, as the water passes over the edge of the vane and falls on the tread of the first step, that there is scarcely any noticeable break-up.

On the 1:20 scale (Fig. 10), where the fall of the water exerts a force 15.6 times greater than on the 1:50 model, a considerable break-up is noticeable where the water falls over the vanes and crest and impinges on the first step.

On the 1:8 scale (Fig. 11), the force exerted by the falling water is 15.6 times greater than in the 1:20 model, and 244.1 times greater than in the 1:50 model. In this case, there is a marked break-up in the jet as it flows over the first step. In no place is the smoothness so noticeable as in the 1:50 model, or even in the 1:20 model.

Some idea of the break-up which will occur in the full-scale prototype, may be obtained by first comparing the 1:50 and 1:8 models, in which the force ratio is 1:244.1, and then attempting to visualize the full-scale model in which the force will be 512 times the 1:8, or 125 000 times the 1:50, model.

The dissimilarity in models below Step 1 is probably best shown on Fig. 9. On this diagram, the outer edge of the jet has been plotted for a proportionate head of 5 ft. It will be noted that, generally speaking, the difference in force has had the effect of placing the outer edge of the jet a little farther away from the weir as the scale increases. The experiments seem to show, however, that, in this model, the center of the jet remains in approximately the same location for all heads and that the break-up simply increased the area of the jet. In this connection, it will be noted that the area of the jet flowing over Step 1 is larger in the 1:8 scale than in the 1:20 scale. (See Fig. 9.)

It must be noted, however, that below Step 4 this is only conjecture, as the 1:8 model did not extend below that point. It is thought that the outer edge of the jet on the full-scale model will be proportionately farther out, or, in other words, it may be exterpolated from the location of the jets on the three models. This is assumed by noting that the general location of the outer edge of the jet of the 1:20 model is midway between the 1:8 and 1:50 models.

As a further check on the theory that the dissimilarity in models of stepped overfall dams is caused partly by variation in force, exercised by the falling water, due to the scale of the model, reference is made to the studies of the flow over Section 16.

Between Steps 3 and 5, the location of the outer edge of the jet varies with the scale of the model, its distance from the dam being greatest for the 1:8 scale. Probably the principal cause for this is that the energy of the jet, as it impinges on Step 2, is greatest for the 1:8 model, thus causing the jet below that point to be projected farther than in the other models.

From measurements taken in the field, on flows over the flat-crested weirs, it was possible to determine with considerable accuracy the area of the jet on the down-stream edge of the crest, and with this area and the computed quantity, the velocity was calculated. Table 4 shows the computed velocities, in comparison with the theoretically proportionate velocities. The theoretically proportionate velocities were determined by assuming the velocity for one scale as standard, and computing the other by multiplying or dividing by the square root of the scale ratio.

TABLE 4.

Model.	Computed velocity, in feet per second, assumed as actual velocity.	Assuming 1:8 model as standard.	Assuming 1:20 model as standard.	Assuming 1:50 model as standard.
1:8	4.99	......	5.02	5.11
1:20	3.18	3.16	......	3.23
1:50	2.045	2.00	2.01	......

It will be noted, that the proportionate velocities shown in Table 4, do not differ greatly from the velocity assumed as correct, but they do differ sufficiently to change the curve of the jet so that it will not check the curve measured in the field.

As already stated, therefore, the writers conclude that flows over models of broad-crested weirs, although giving results that approximate closely those over the prototype, do not show an identical similarity, owing to the fact that the coefficient of flow over a broad-crested weir is not always proportional to the ratio of head and width of crest, due largely to the disproportionate effect of skin friction and viscosity.

By computation, it can be shown that by changing the geometrical similarity to a slight degree, that is, by using a corrected head, flows may be obtained which are identically similar for all models. Thus, if instead of a 6-ft. proportionate head, (0.75-ft. head (actual scale), on the 1:8 model), a head of 0.69 ft., actual scale is substituted, a quantity is obtained that corresponds with the quantity computed for the full-scale model. For the 1:20 scale, the head will be 0.255 ft. instead of 0.30 ft. (both actual scales), and for the the 1:50 scale; 0.10 ft. instead of 0.12 ft. These results have never been checked in the field, but are thought to be fairly accurate as the retardation of velocity, due to a broad crest, increases with the scale of the model.

Owing, largely, to the effect of skin friction and viscosity, the jets, over model flat-crested weirs, do not exactly check each other. A description of these weirs and the tests on them has already been given. It remains to prove theoretically why these jets do not follow the same line when plotted on a proportionate scale (Fig 13). If these jets followed the same line, the

velocities would be in proportion to the square root of the scale ratio, and the coefficient, $\frac{c}{C}$, would equal unity. (See page 1518.)

The following paragraph is quoted from a paper by Richard R. Lyman, Assoc. M. Am. Soc. C. E., entitled, "Measurement of the Flow of Streams by Approved Forms of Weirs with New Formulas and Diagrams,"* in which a graph is shown giving heads and corresponding discharges over broad-crested weirs:

"It should be noted that, for comparatively low heads, all these broad-crested weirs give practically the same result for the same head. At a particular head or point, however, for each width of crest, the quantity of discharge begins suddenly to increase much faster, in proportion to the head, than it has done before, and the line representing its discharge breaks away from *AA* and extends across the diagram [Plate XXIV] in a slanting direction to the line, *BB*, which represents the discharge over weirs with sharp crests."

A study of this statement and the graph will lead one to believe that the models of broad-crested weirs, on different scales, will not check. If they were identically similar, the lines representing width of crest would be straight and not broken. If the action of a model is precisely similar to its prototype, then, in the formula for discharge over broad-crested weirs,

$$Q = C\, 3.33\, L\, (H)^{\frac{3}{2}},$$

C, which depends on width and head, should be a constant for the model and its prototype, regardless of the scale of the model, as in the model the ratio of width and head would be the same as in the prototype. A table† compiled by Gardner S. Williams, M. Am. Soc. C. E., from the Cornell experiments on flow of water over weirs, will prove that this is not true. As an example: With the head of 2 ft., and a width of crest of 1.65 ft., the coefficient is 0.925. Multiplying both head and width of crest by 2, the coefficient is 0.807.

As a further check, the flow over a weir 30 ft. long, 6 ft. wide on the crest, with a head of 6 ft., with end contractions, was computed, using the formula,

$$Q = 2.64\, (L - 0.2\, H)\, H^{\frac{3}{2}}; \ddagger$$

for the models, the following formula was used,

$$Q = 3.33\, (L - 0.2\, H)\, H^{\frac{3}{2}},$$

with the exception that for the 1:8 model a correction was applied for broad crest. These computed flows were then compared with proportionate flows obtained by the formula,

$$\frac{Q}{q} = \frac{A \sqrt{2\, G\, H}}{a \sqrt{2\, g\, h}}.$$

The results of these computations are shown in Table 5.

* *Transactions*, Am. Soc. C. E., Vol. LXXVII (1914), p. 1199, and Plate XXIV, p. 1205

† "Waterworks Handbook", by Messrs. Flinn, Weston, and Bogert, Table 196, p. 601.

‡ Merriman's "Hydraulics", p. 161.

TABLE 5.

Model.	Computed flow, in second-feet.	Comparison with full scale, second-feet.	Comparison with 1:8 scale, second-feet.	Comparison with 1:20 scale, second-feet.
Full scale	1117.7	......	......	......
1:8	7.018	6.16	......	......
1:20	0.7864	0.625	0.7107	......
1:50	0.081	0.059	0.064	0.073

This proves that, in models of broad-crested weirs, as $\frac{c}{C}$ does not equal unity, mechanical and geometrical similarity cannot be obtained simultaneously, owing, in all probability, to the proportionately different effect of skin friction and viscosity. In determining the proper quantity for this tabulation, it seems best to use that quantity, the computed jet of which plotted closest to the actual jet as measured in the field.

For each flow, the quantities were computed by each of the following formulas: Bazin, Fteley and Stearns, Francis, and U. S. Geological Survey. Using the velocity derived from these formulas, paths of the jet were plotted by applying the jet formula,

$$x = vt, \; y = \frac{1}{2} g t^2,$$

and compared with the curves that had been determined in the field by locating the inner edge of the jet. The accepted quantity for each flow was that one the jet of which was nearest to the jet located in the field. Similar computation sheets were made for the 1:20 and 1:50 models.

For comparison, the theoretical parabola, derived from the formula:

$$x = \frac{2}{3} \sqrt{2\,g\,h}\; t\,^*, \; y = \frac{9}{16} \frac{x^2}{h},$$

was plotted. This line was considerably under the inner edge of the jet as measured, and, therefore, does not represent as great a velocity.

The main causes, therefore, for the dissimilarity in action over these models are: Difference in force; difference in coefficients of flow over a broad-crested weir, due to skin friction and viscosity; and difference due to atmospheric pressure, when parts of the flow are not open to free circulation of air.

Effect of Dissimilarity of Models on Experiments with Flow in Channel.— In the final experiments with the flow in the channel, Section 16 of the dam, on the 1:50 scale, was used. No experiments were made with models of any other scale, nor have experiments been made using the accepted section of the dam, Section 100. It is thought that the revised section will tend to bring the water to the floor of the channel with a lower velocity than Section 16. However, the force exerted by the falling sheet of water will be 125 000 times greater than that in a model on the scale of 1:50. With the present limited knowledge, it would be inadvisable to predict just what the action in the channel will be.

* Encyclopædia Britannica, Vol. 14, p. 51.

General Conclusions

From observations, measurements made in the field, careful study of photographs, and a study of the theory of models, the writers conclude:

1.—That the flow over a large scale dam will be similar to a certain degree, but not identical with the flow over its models.

2.—That, as Mr. Groat has pointed out, it may be possible to build a diminutive structure, not necessarily a model in the true sense of the word, which "must reproduce, even in detail, the performances of their prototypes", but that, in many cases, the practical difficulties encountered may make the construction and test of these models impractical. For instance, in order to obtain a proportionate test for the force of the falling water on the steps of the Gilboa Dam, it would be necessary to build a model on a scale of 1:2.38 and test with mercury at 60° Fahr.

3.—That, with a full recognition of the fact that there is dissimilarity, the model, if built on a large enough scale, still remains the most efficient method of determining the most satisfactory section for an overfall dam.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

ENGINEERING GEOLOGY OF THE CATSKILL WATER SUPPLY

By Charles P. Berkey,* Esq., and James F. Sanborn,† M. Am. Soc. C. E.

To Be Presented October 4th, 1922

Synopsis

This paper deals with the geological features involved in the location, design, and construction of the Catskill Water Supply System of the City of New York.

The purpose is to discuss the intimate relation of applied geology and certain phases of engineering work, to present illustrations of the method used by the engineers in solving, through the correct use of geological information, some of the problems involved, and to show the relations of these engineering problems to the natural features and conditions of the country in which the work is located.

General Conditions

In planning the construction of a water-works system comprising an aqueduct more than 100 miles long, together with several dams and other structures, the choice of location, design of structures, and details of construction were greatly influenced by the form, relief, and underground condition of the country traversed. Seldom in a large public enterprise of this kind, has so much trouble been taken to discover and to work out the important relations of topographic form and underground structure, and to apply the results of

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion on this paper will be closed with the December *Proceedings*, and when finally closed, the paper, with discussion in full, will be published in *Transactions*.

* Prof. of Geology, Columbia Univ., New York City.

† Cons. Engr., New York City.

these studies to the problems of location, design, construction, and operation of the completed system. Indeed, it was necessary to success that all the conditions be known in detail. The selection of proper dam sites, with foundations sound enough to support the enormous weight of the dams and impervious enough to prevent leakage, demanded a careful investigation and study of all the intricacies of the physical condition and behavior of the ground. The expedient of conveying water in tunnels driven deep in bed-rock, under great hydrostatic pressure, was adopted only after sufficient information was available to give confidence in the general stability of local geological conditions.

The importance of these conditions in controlling the location of the aqueduct is well illustrated in the choice of the crossing of the Hudson River, the final selection of which involved a change in the position of the entire aqueduct line west of the river. Fig. 1 is a map of the Catskill Water Supply System. The principal types of construction included in the project are as follows:

(*a*) Three high masonry dams;

(*b*) Several miles of earth dikes with core-walls; and

(*c*) An aqueduct, made up of the following parts:

Cut-and-cover aqueduct	51.0 miles
Grade tunnel (including Shandaken Tunnel)...	31.7 "
Pressure tunnel	35.6 "
Pressure aqueduct	4.8 "
Steel pipe siphons	6.2 "
Pipe conduit	15.4 "
Total	144.7 miles

In the construction of pressure and grade tunnels, sixty-seven working shafts, from 150 to 1 100 ft. in depth, were sunk.

Geological Investigations

The development of the Catskill Water Supply System has been influenced by geological factors to a greater extent than is usual in most engineering enterprises. This is due in part to the great distance the water must be carried to reach New York City, the topographic and structural complexities and peculiarities of the intervening country, and the general plan of operation chosen for this particular system. Because of the type of design of the Catskill Aqueduct and the peculiar relief of the country, it was evident early in the work that many grade tunnels would be required to pierce the mountain ridges standing above hydraulic grade along any possible route. It was also found that it would be more economical, and would result in a more successful and permanent public work, if the valleys and river courses which lie much below hydraulic grade, were crossed by pressure tunnels constructed in the bed-rock.

The earliest studies indicated certain places where thorough exploration would be needed. One such place was the trough or inner valley of the Hudson River, which presented an unusual problem in the question of depth

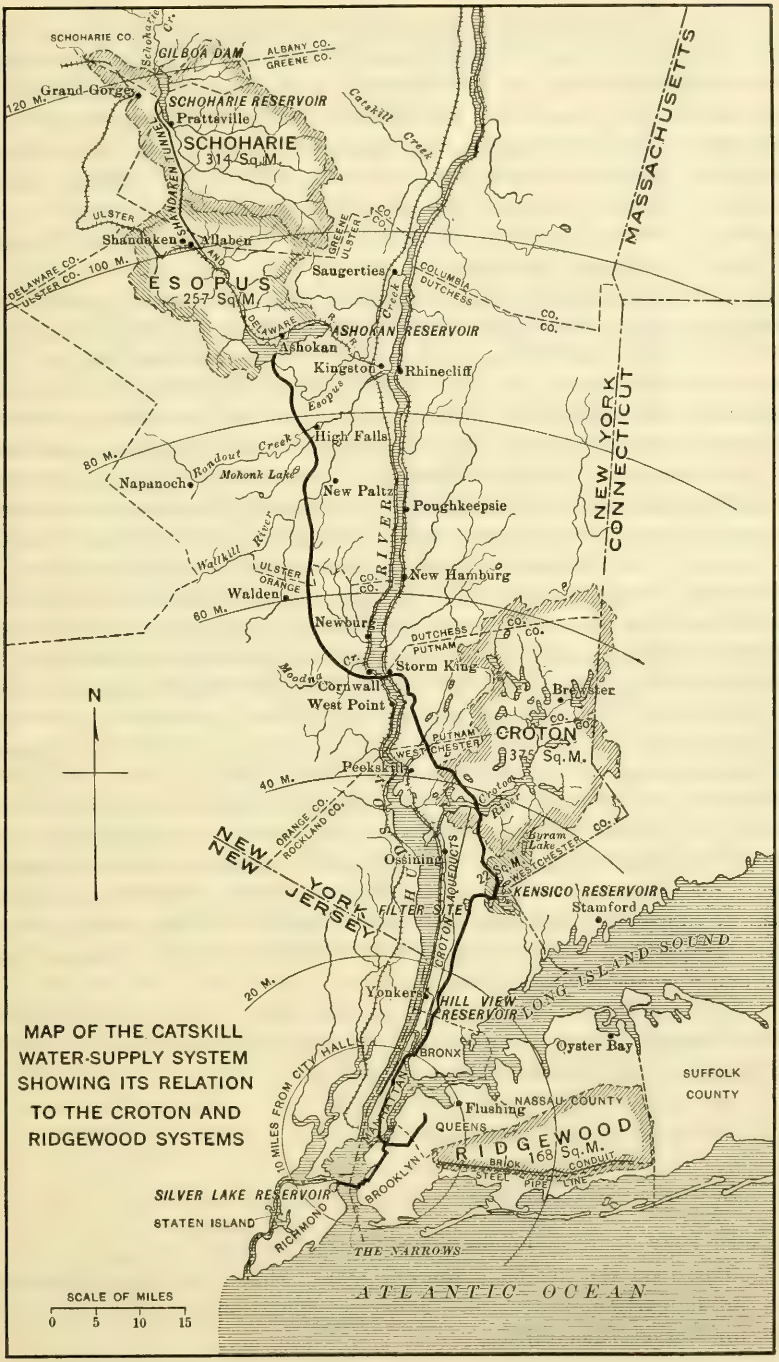

MAP OF THE CATSKILL
WATER-SUPPLY SYSTEM
SHOWING ITS RELATION
TO THE CROTON AND
RIDGEWOOD SYSTEMS
SCHOHARIE CO.
GILBOA DAM
ALBANY CO.
GREENE CO.
Grand-Gorge
SCHOHARIE RESERVOIR
Prattsville
SCHOHARIE
314 Sq.M.
Catskill Creek
SHANDAKEN TUNNEL
ULSTER
Shandaken
Allaben
Saugerties
ESOPUS
257 Sq.M.
DELAWARE CO.
ULSTER CO.
100 M.
120 M.
COLUMBIA
DUTCHESS
ASHOKAN RESERVOIR
Ashokan
Kingston
Rhinecliff
MASSACHUSETTS
NEW YORK
CONNECTICUT
High Falls
80 M.
Rondout Creek
Napanoch
Mohonk Lake
New Paltz
Poughkeepsie
Wallkill River
HUDSON RIVER
New Hamburg
Walden
60 M.
Newburg
DUTCHESS
PUTNAM
Storm King
Cornwall
West Point
Brewster
CROTON
375 Sq.M.
Peekskill
40 M.
Croton River
Byram Lake
ORANGE CO.
ROCKLAND CO.
NEW YORK
NEW JERSEY
Ossining
CROTON AQUEDUCTS
FILTER SITE
KENSICO RESERVOIR
Stamford
LONG ISLAND SOUND
20 M.
Yonkers
HILL VIEW RESERVOIR
BRONX
Oyster Bay
SUFFOLK COUNTY
10 MILES FROM CITY HALL
MANHATTAN
Flushing
NASSAU COUNTY
QUEENS
RIDGEWOOD
168 Sq.M.
BRICK CONDUIT
STEEL PIPE LINE
BROOKLYN
SILVER LAKE RESERVOIR
STATEN ISLAND
RICHMOND
THE NARROWS
ATLANTIC OCEAN
SCALE OF MILES
0 5 10 15
N

FIG. 1.

to bed-rock. To collect and to state the broad facts relating to this and many other situations, the services of Professor W. O. Crosby, of the Massachusetts Institute of Technology, and of Professor J. F. Kemp, of Columbia University, were obtained as Consulting Geologists. The studies undertaken by the geologists covered a wide range, bearing on the origin of the rocks, the processes which modified or preserved them, the influence of climatic changes, the effect of former elevation and depression of the earth's crust, the interpretation of surface features, and many other factors which tend to modify, preserve, or to destroy the rocks.

In projects of this kind it is important for the engineer to submit to the geologist certain rather definite questions relating to the engineering requirements. It is not practicable to investigate wholly unrelated matters in the early stages of the work. In the beginning, the geologist's advice was sought in directing the exploratory work to supplement the data already secured as the boring work developed. In the course of the investigations and studies for the engineering design and location of the Catskill System, information was secured relating to the suitability of materials of construction, comparison was made of factors affecting the cost of excavation, facts relating to the water-bearing quality of the rocks and soils to be penetrated, and the influence of the rock on the structures contemplated. One question studied was whether the tunnels far below the surface might be damaged by earthquake shock, or are otherwise unstable, and whether there are special sources of trouble or weakness in the rock, such as acid-bearing waters with their own peculiar destructive influence. The range of information ultimately required covered such special features as a comprehensive regional study of pre-glacial topography and drainage, and the distribution of the glacial drift as a basis for indicating the location and probable depth of the buried gorges of pre-glacial streams, the contour of the bed-rock surface, a discussion of the condition of the several formations to be met, their behavior under excavation, underground water circulation, the occurrence of zones of weakness indicating the probable extent of tunnel roof support required, the location of folds, faults, and other rock features, with a consideration of their effects on the construction operations and permanence of the work.

General Questions.—The engineering questions involving geological facts and interpretation which arose in connection with the Catskill Aqueduct project may be grouped as relating to:

A.—Topographic features;

B.—Over-burden, or glacial drift;

C.—Kind and character of the rock; and

D.—Advisory matters.

Under Item *A*, the following questions were studied:

1.—Based on the available contour maps, where are the most promising sites for the particular structures under consideration, for example, the main dams for storage reservoirs?

2.—Do the surface features indicate whether the relief is controlled by the glacial drift or by erosion of bed-rock?

3.—Considering the larger topographic features, such as the main valleys and their origin, is there any likelihood of finding deep buried gorges requiring extensive exploration?

Under Item *B,* the following questions arise:

1.—What is the thickness and distribution of the over-burden, or drift, in the area involved?

2.—Is there unusually deep cover at any particular place, or a pre-glacial gorge of uncertain depth?

3.—What is the character of the over-burden? Is it residuary soil, stream deposit, or glacial drift? Is it impervious or very porous? Will it be firm or cave in excavation? Are extensive exploratory borings or test-pits required?

Under Item *C,* some of the questions are:

1.—What is the probable rock-floor contour or profile? What is the rock formation or kind of rock forming the floor, its quality, and structural character? Is it porous or reasonably impervious?

2.—Is there danger of weathering, disintegrating, or swelling of the rock in tunnel excavation or open cuts? Is there likely to be considerable depth of decayed or weathered rock on top of the ledge proper?

3.—Is the rock massive or bedded? If sedimentary, what is the structural attitude? Is it faulted and folded? If the rock formation at a particular location or depth is questionable, is there a possibility of finding more satisfactory conditions either by a shift of line to a new location, or a change in depth?

Under Item *D,* the following questions may arise:

1.—Where should the exploratory work be located and the borings placed, and to what depth?

2.—Is the proposed project feasible from a geological standpoint, or are the natural difficulties insurmountable?

3.—Are there any special precautions to be taken at certain points during construction? What special points must be covered in the contracts?

4.—Is the locality capable of producing suitable stone for use in construction?

5.—Is there any likelihood of the disturbance of local conditions by the work of construction, such, for example, as change of water level, interference with local water supply, or weakening of foundations? Are the geological conditions such as to expect claims for either temporary or permanent damages due to construction?

The most economical method of exploration as far as it can be stated in general terms is to base it first on a thorough geological study, to check and interpret all data as gathered, and modify, if necessary, any additional exploratory work in accordance with the results already secured. A working hypothesis is essential. The engineers found it helpful to obtain the advice of a geologist in the interpretation of the exploratory borings as these were made, so that the next hole could be located at the spot most likely to give

further results in the light of the existing knowledge. By this method, much time was saved and the borings were made to give useful information. The methods of securing underground data included, in addition to surveys and mapping, the use of (1) test-pits, shafts, and trenches; (2) tunneling; (3) borings of various kinds; (4) pumping and pressure tests of drill holes; (5) laboratory tests, and microscopic examination; and (6) chemical analysis.

Geology of the Region Traversed by the Catskill Aqueduct

The relief features and geologic structure of the country traversed by the Catskill Aqueduct is more complex than is generally the case in such a limited area. This region has been affected by mountain foldings and accompanying dynamic disturbances at least three times. The area extends from the undisturbed interior plateau type of country (as represented by the Catskill Mountains), across the entire belt of Appalachian folds (as represented in the Middle Hudson Valley of New York), and the still earlier Taconic deformation belt (as represented in the older sedimentary rocks, especially the Hudson River slates north of the Highlands), the mountainous belt of very ancient geological formations (as represented by the Highlands with the Piedmont belt of crystalline rocks), to the Coastal Plain, including the newer formations along the present seashore. It is a complex region of a long and involved history. Fig. 2 shows the geologic column, representing the succession and variety of rocks encountered in the Catskill Water Supply development. Plate XXI shows a block diagram of the physiographic features, together with the underground geologic structure of the Lower Hudson region and the course of the Catskill Aqueduct.

Beginning with the areas occupied by the water-sheds, the chief types of country are as follows:

The Catskill Plateau, characterized by an elevated upland of little disturbed, rather flat-lying sediments, dipping gently westward, made up mostly of fine-grained sandstones and still finer shales.

South of the Catskill area is the Appalachian Province forming a belt running northeast-southwest, paralleling the eastern edge of the Continent. This belt has shared in the folding and other movements which have been responsible for the structural complexity of the strata and have controlled the relief habit of the present surface. A part of this belt, now somewhat lower and apparently less ridged than the remainder, forms what is known as the Great Valley. The compressive or mountain-building forces which produced the Appalachian Belt, acted in a general northwesterly direction and produced folds of remarkable continuity, accompanied by a series of great faults running parallel with the main ridges and valleys, or generally northeast and southwest. The whole province is crossed by the Catskill Aqueduct.

Still farther south the country changes again, and one finds there the ancient Archean land mass, represented to-day by the gneisses and granites of the Highlands. In this belt, all the rocks are crystalline. They belong to an extremely old series, possibly the oldest known in the eastern part of the United States. Doubtless, originally many of them were sediments similar to those occupying the districts farther north, already described; but, subsequently, they


LOWER HUDSON REGION
CATSKILL
AQUEDUCT
CATSKILL MOUNTAINS
MOUNTAINS

GEOLOGIC COLUMN	NAME OF FORMATION	THICKNESS IN FEET	AGE	LOCALITY
	Catskill Conglomerate	300	Devonian	Catskill Mountains
	Oneonta Sandstones and Shales Ashokan Flags Hamilton Flags Marcellus Shale	3 000 ±		
	Onondaga Limestone Esopus Shale Helderberg Limestones	350 ±		Rondout Valley
	Binnewater Sandstone High Falls Shale	120	Silurian	
	Shawangunk Grit Unconformity	300 ±		Shawangunk Mountains
	Hudson River Shales, slates and graywackes	3 000 — 5 000 ±	Ordovician	Hudson and Wallkill Valleys
	Wappinger Limestone	1 000	Cambro-ordovician	Hudson Valley
	Pouquag Quartzite Unconformity	600	Cambrian	
	Archaean Gneisses and Granites Manhattan Schist Inwood Limestone Fordham Gneiss Yonkers Gneiss	Great Unknown	Pre Cambrian Complex Rocks Crystalline and Metamorphic	Highlands of the Hudson, Westchester County, New York City.

FIG. 2.

were affected by metamorphism and invaded by igneous intrusions of many kinds, especially by granites, and thus became not only much modified from their original condition, but also much disturbed and distorted. In their present condition, they form the most complex belt with which this work has had to deal.

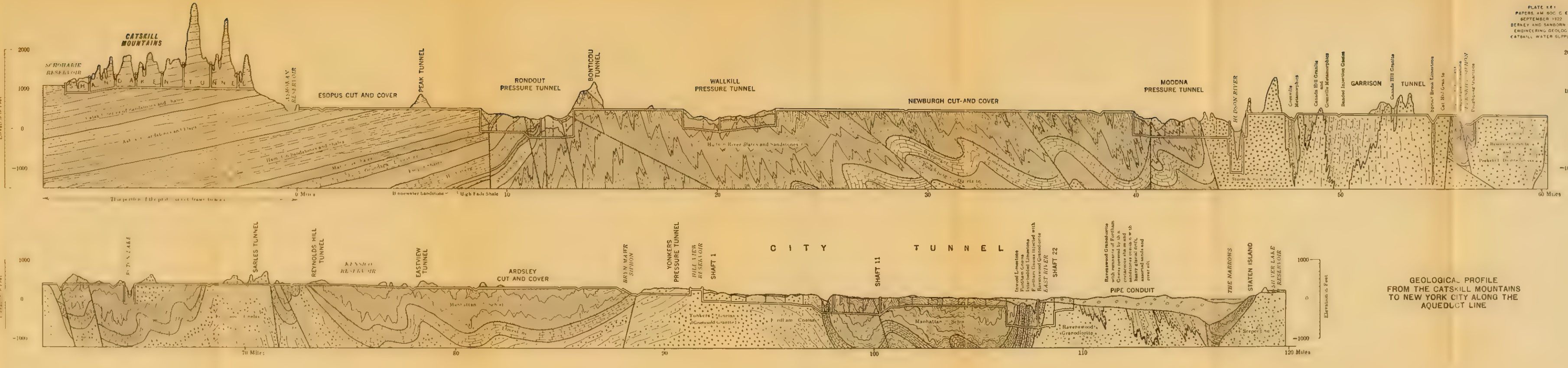
Although the Highlands proper is a narrow belt not more than 20 miles wide, the same kinds of rocks to a large degree extend continuously on the east side of the Hudson River to New York City. For 50 miles, the aqueduct has been located through and over these complex rocks. The southerly part of this unit has more moderate relief than the Highlands proper, and its surface gradually becomes lower and lower, passing beneath sea level in the vicinity of Long Island Sound and New York Bay, only the Highlands Belt being mountainous.

The last of the distinctly different districts follows the immediate border of the Atlantic between Long Island Sound and the sea, including also a part of Staten Island. It is the northerly extension of the great coastal belt which, farther southward, becomes much wider and much more prominent as a physical unit. This belt is characterized by simple sedimentary strata of clay, sand, and gravel which lie almost flat, but really dip gently toward and beneath the sea. They are the simplest of the formations with which this work has been concerned, but are of prime importance, especially in connection with the water sources of Long Island. These great provinces differ strikingly in physical make-up, structure, and age. Each is complex, is structurally a group of physical units or formations distinguishable among themselves, and each presents its own peculiarities of behavior and geological significance.

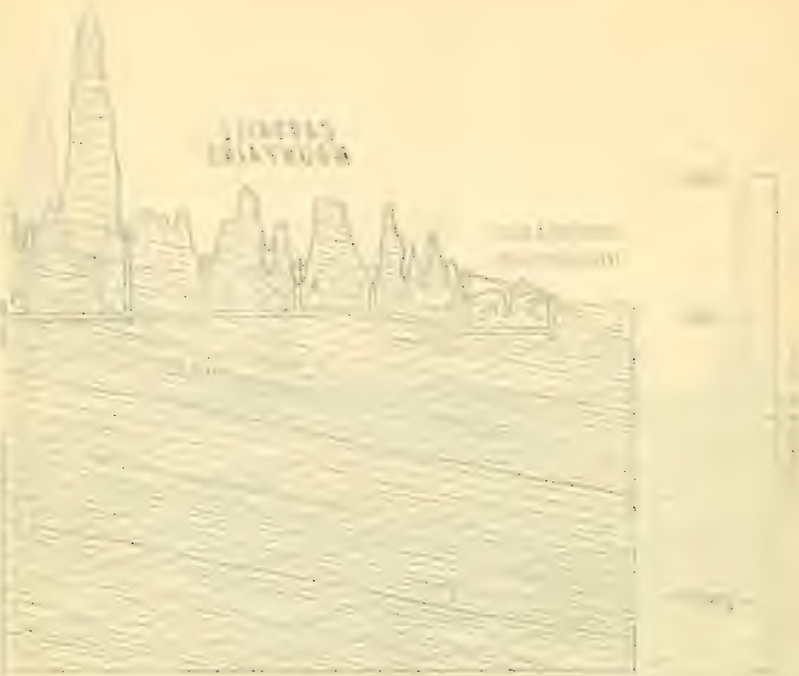
Geologic History.—The oldest of all the rocks are certain parts of the crystallines of the Highlands. These rocks are doubtless old sediments formed in the sea and by running water. They were a great series which was folded into mountain ranges in ancient times. Subsequently, they were invaded by immense floods of igneous material, which literally swallowed large parts of the solid foundations of that time and formed huge igneous masses now appearing as granites and other massive rocks. Rocks of intermediate composition were formed, doubtless by a mixture of the two original types—the sediments and the invading igneous material. This is well shown on the geologic profile, Plate XXII, from the Catskill Mountains to New York City along the aqueduct line.

These changes took place at great depth. The superficial formations of that time have been carried away by erosion. Only the roots of this ancient mountain range are now exposed, and they are the crystalline rocks of the Highlands. How much erosion took place no one can say, but after ages of erosion, so long indeed that the rivers of that time and the sea had cut away all the superficial material and had exposed the already cooled and crystallized igneous masses, the sediments that now form the other rocks began to accumulate. The land area lay along the Atlantic border and extended an undetermined distance into the present Atlantic Ocean. The sea lay to the west and in it were deposited the sediments carried down from this land area, first the sandstone, limestone, and shale of the present Hudson Val-

PLATE XXI
PAPERS, AM. SOC. C. E.
SEPTEMBER, 1922
BERKEY AND SANBORN ON
ENGINEERING GEOLOGY
CATSKILL WATER SUPPLY



GEOLOGICAL PROFILE
FROM THE CATSKILL MOUNTAINS
TO NEW YORK CITY ALONG THE
AQUEDUCT LINE



ley, and after several thousand feet of these sediments had accumulated a new mountain folding and another period of erosion took place.

When deposition began again, it formed the great series of sediments that now lie above the Hudson River shale series. The Shawangunk conglomerate was the first, and on it were accumulated, one after another, the shales, limestones, and sandstones that now constitute the rocks of the Rondout Valley and the Catskill Mountains. Then came the Appalachian mountain-making period, the last great folding movement to affect this region. Since that time, conditions have been completely reversed. The region to the west became a continental area and the re-adjusted drainage from this new continental area carried the sediments of subsequent time toward the east into the Atlantic. A long period of erosion followed, and, with the shifting of levels, the Atlantic gradually encroached from the east, covering a part of the old land area that originally furnished most of the earlier sediments.

In this long period of erosion and unchanged sea level, there was opportunity for the streams of the new Continent to wear the whole region down almost to a plain. The development in this "almost-plain" took place in the Cretaceous period, and, therefore, is referred to as the "Cretaceous peneplain." During part of this time and, subsequently, sediments have been accumulating on the Atlantic Coast. These are simple beds that are not much distorted. The Cretaceous peneplain still persists in a somewhat fragmentary form, because of much subsequent erosion. From a high elevation it can be plainly seen in distant landscape, as, for example, in the level sky-line of the Hudson Highlands, the Shawangunks, and parts of the Catskills, and more definitely in the remarkably uniform seaward slope of the crystalline rocks south of the Highlands passing under Long Island out beneath the sea. Its existence is shown by the boring profiles across Long Island to depths of 1 000 ft. and more below sea level, where the soft Cretaceous beds of the Coastal Plain lie on the old erosion floor of that time.

An elevation of the Continent of from 1 000 to 2 000 ft., during the Tertiary period, gave the streams a steeper slope toward the sea, with greatly increased velocity and cutting power, so that the old Cretaceous surface was deeply dissected by the streams cutting new valleys along the more easily eroded rocks. In the course of time, a new base level of erosion was reached in places where the rocks were comparatively soft, such as limestones and slates. This new peneplain, however, was never finished. The region was elevated again before the erosion was completed, and new trenches began to be cut by the streams. Traces of this Tertiary peneplain are readily seen, however, in the rather even stretches of ground, at 300 to 500 ft. above sea level, in the broad valleys of the Hudson and its tributaries. The importance of the questions previously discussed relates closely to the problems in the location of the Catskill Aqueduct, in the depths of old buried stream valleys and their effect on the location of tunnels. The Tertiary peneplain was a feature of great significance in determining the course and hydraulic grade of the aqueduct. The 15-mile section of cut-and-cover aqueduct from the Wallkill to the Hudson River is made possible at its present grade by the existence of this old peneplain. The subsequent continental elevation that

ended the development of the Tertiary peneplain and caused the renewal of trenching, finally started the Glacial epoch, and an entirely new set of conditions were thus established, which led to changes of far-reaching importance. This elevation probably ultimately amounting to several thousand feet, at first simply increased the cutting power of the streams and resulted in renewed trenching of the valleys, with the development of rather narrow deep gorges, extending far below the general Tertiary base level. These gorges still remain beneath the glacial drift cover, some of them extending several hundred feet below sea level.

The Glacial Period.—The ice invasion that followed, covered the entire region, including the Catskills and the Highlands, the ice occupying even the highest summits and spreading southward to Long Island. There, the ice melted, forming the Terminal Moraine which extends the length of the Island and crosses the Narrows to Staten Island, thus marking the southern limit of the great continental ice sheet. At the height of its activity, as it moved southward, the planing action of the ice mass smoothed the tops of hills and ridges, ploughed deeper in some of the softer material of the valleys, and scraped hard against all exposed northerly slopes. At the same time, particularly as the ice finally thawed, the deeper canyons and valleys were buried with glacial drift, thus modifying greatly the surface contour of the country and tending by these processes of erosion and deposition, to smooth the more rugged earlier topography. One of the results of this action is the buried channels and drift-filled gorges. The present streams scarcely anywhere flow in their original channels, nor even on the old valley bottoms. On this account it was necessary repeatedly to determine, by boring, the location and the depth of these old pre-glacial channels.

The damming of valleys by glacial ice and drift created lakes and gave opportunity for the development of silt deposits in them. Subsequent partial or complete removal of such barriers and final drainage of these temporary reservoirs are factors of important bearing in this region. The Ashokan Reservoir occupies, in part, one of these glacial lake basins. The material left behind by the ice sheet is a mixture of mineral and rock matter derived from the removal, transportation, and deposition of former residuary soils and partly disintegrated rock gathered up as the glacier moved slowly over the surface of the country. Some of it is a mixture of pebbles, boulders, sand, and clay, which was not assorted by the action of water. This is the so-called "glacial till", also known as "hardpan", when consolidated. Other parts of the drift were worked over by the water from the thawing ice and thus were more or less assorted so that the materials became separated as deposits of sand, gravel, and silt or clay. These deposits constitute the so-called "modified drift" deposits, which, unlike the till, are generally loose and unconsolidated.

It would be a comparatively simple matter to classify these glacial materials and judge their behavior if they were as distinct, continuous, and uniform from top to bottom as the average rock stratum. However, they are much more likely to be variable in every respect and the different types of these materials grade one into another in a most confusing manner. They exhibit

important differences in their capacity for holding water. Thus, the character of the drift becomes an important factor in the choice of location for dams and dikes. In fact, they were controlling factors in the location of the Ashokan Dam.

Ancient Drainage.—In a study of the possible crossings of the aqueduct under the Hudson and its tributary streams, the old courses of the pre-glacial channels and particularly their depths, were vital factors in the design and location of the pressure tunnels.

In this district there is only one main drainage channel, the Hudson River, to which all the other streams are tributary. These tributaries have attained their present courses by the general northeast-southwest strike of the rock formations, the different members of which are strongly contrasted in their resistance to erosion. It thus happens that whereas all the tributaries on the east side of the Hudson are direct, those on the west side are retrograde, that is, flow somewhat opposite to the direction of flow of the master stream and join it at an obtuse angle. The Wallkill River is a remarkable example of this. It rises within 40 miles of New York Bay, and flows northeasterly, following the formational direction for 75 miles, getting farther and farther away and finally reaching the Hudson nearly 90 miles from the sea. On account of the glacial drift cover, many of these stream valleys are heavily filled and the present stream courses diverge greatly from these former lines. Still, the old courses were of greatest importance in the problems of the aqueduct. Thus, it happens that a working knowledge of the origin and habit of the pre-glacial drainage has been of greater practical service than the simple statement of its features would lead one to expect.

The Catskill Mountain Water-Sheds

The selection of the Catskill Mountains as a source of the new water supply of New York City was made because this area was found to be the one which, by reason of its large, sparsely inhabited, and well-wooded mountain slopes, is certain to yield an adequate quantity of water of exceptional softness and purity. The site chosen for the main storage reservoir, 100 miles from New York City, in the southern edge of the Catskill Mountain area, is at such an elevation that the water from it can flow by gravity through the aqueduct and distribution systems, thus eliminating the cost of pumping. Because of the steep mountain slopes, the water runs rapidly down the rocky stream beds, encountering on its way almost no swampy ground or stagnant ponds. Even almost all the water that sinks into the soil and enters bed-rock returns clear and pure to the regular drainage courses at the lower levels in the immediate district, because the beds lie nearly flat and have many interbedded tight shale members to obstruct the downward course of the water.

The gathering ground in the Catskills lies entirely in a region of sandstones and shales, without much admixture of limy fossil remains and no limestone beds. Such rocks are very resistant to solution and, for this reason, the water which flows over and percolates through them, dissolves so little mineral salts that a water unusually soft and pure is supplied.

The sedimentary beds consist of alternate layers of hard sandstone and soft shale, with wide variations in quality and in thickness of individual beds. In many places, the sandstone is of the quality known as bluestone, and has been extensively quarried. Generally, the strata dip to the west at a small angle, and there is no marked deformation. In a broader view, the region may be regarded as a deeply dissected plateau of which the rocks of different hardness, lying in beds dipping gently westward, give form to the back slope of the uplands, whereas the edge of the Catskills toward the Hudson Valley, presents a pronounced eastward-facing scarp, rising abruptly several hundred feet above the valley floor. Erosion has been carried so far that the most elevated remnants have a mountainous aspect. Below these high peaks, the country is more open and uniform, being part of an old base level, or peneplain, judged to be the Cretaceous peneplain referred to previously. Deep canyons and high cliffs are common, with piles of broken rock at their bases. Glaciation has modified the original rugged features, especially the minor details to some extent, and glacial deposits have changed the drainage in many of the valleys, so that the present streams do not follow the courses of the old pre-glacial channels.

The dark sandstones, locally known as bluestone, with the associated shales, are simple sedimentary formations of great lateral extent and thickness. They were laid down as delta deposits, the sedimentary material varying from coarse sand and even small pebbles to the finest silt. The shifting of depositing currents and changes in the supply of materials resulted in a complex structural relation of the beds with frequent variations in the grade of the rock.

This variability in the quality of the rock within short distances is a striking feature in this formation, and was important in the selection of quarries for construction materials. The variation in the grade of the rock also has an important bearing on questions of value, as was illustrated in several large claims for damages where lands were condemned and taken by the City for the Ashokan site. The bluestone, shown in Fig. 3, is a rather fine-grained, dense, and impervious sandstone, very resistant to weathering. Blocks of the bluestone were used in the Cyclopean masonry of the Olive Bridge Dam, and the Gilboa Dam and Spillway will be faced with this material, which is as durable as the best granite. Bluestone is commonly used in New York City for curbs and sidewalk flags.

The Ashokan Reservoir

The main storage reservoir of the Catskill System has an available capacity of 128 000 000 000 gal. The principal structures which form this reservoir are the Olive Bridge Dam, built of masonry, across Esopus Creek, the earth dikes which close the gaps between the hills forming the sides of the reservoir, the dividing dike and weir, which separates the reservoir into two basins, and the waste weir.

The west basin of the Ashokan Reservoir in the Catskills, is shown in Fig. 4. The level top of the old plateau, deeply dissected by streams, is well shown; the stratified rocks dip to the west (left) at a low angle. The flow-line elevation of the reservoir is 600 ft. above tide and the maximum elevations

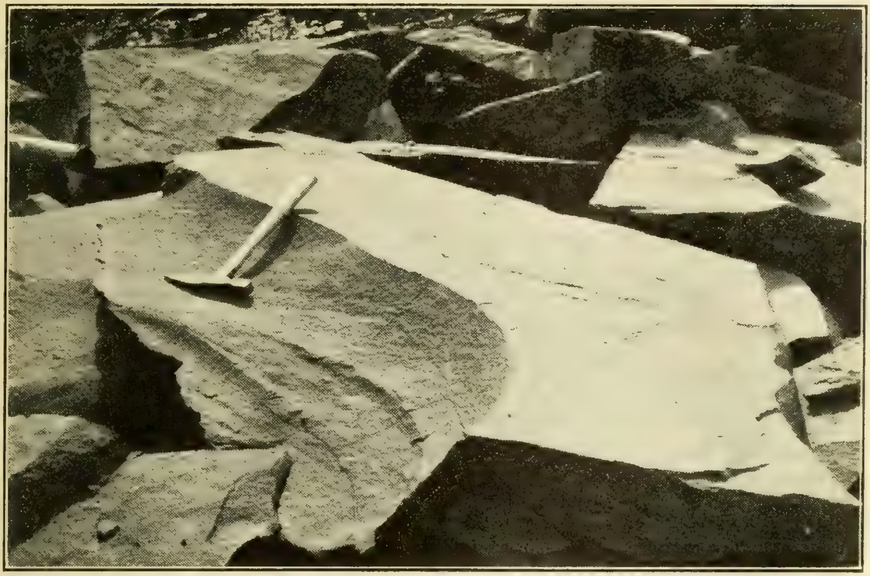


FIG. 3.—SANDSTONE USED ON CATSKILL WATER SUPPLY SYSTEM.

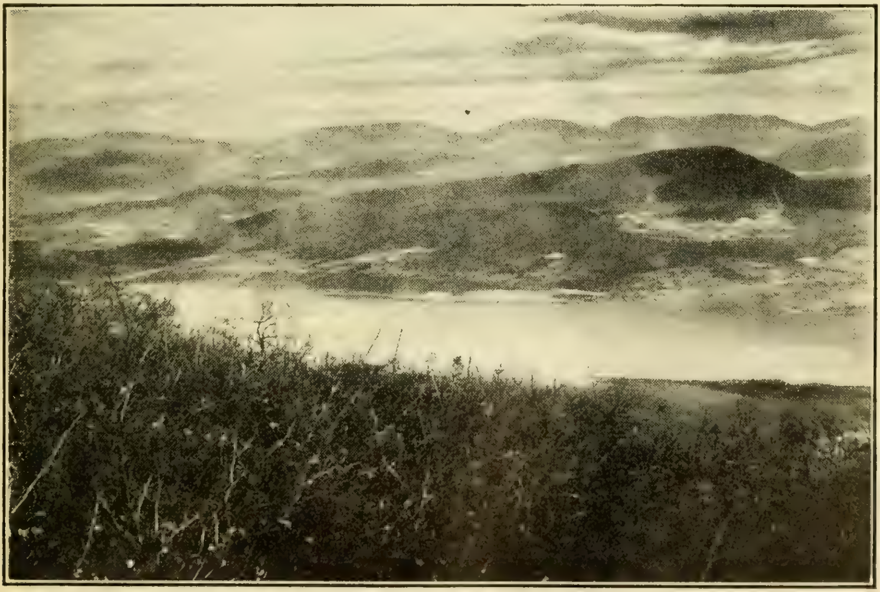


FIG. 4.—VIEW OF WEST BASIN OF ASHOKAN RESERVOIR.

of the mountains in this view are about 3 500 ft. Slide Mountain is 4 200 ft. in elevation.

Its geologic setting is as follows: The continental ice sheet, following the trend of the Appalachian Valley, moved in a southwesterly direction, as shown by glacial scratches. Local glaciers originating in the Catskills may have moved down through some of the main valleys such as the Esopus, but their effects are not very pronounced, and the general ice movement was transverse to this part of the valley. The character of the glacial deposits shows that the ice must have stood in the vicinity of Olive Bridge for a long time in the closing stages, forming an extensive dam, while the melting ice produced a glacial lake in the valley up stream from this dam, where silt and mud were deposited in the form of stratified sand and clay.

Heavy till deposits still form an effective dam at Olive Bridge, but the waters of the lake escaped along the western edge of the valley and cut through the drift, finally reaching bed-rock and cutting a new gorge in it. At the same time, the stream farther up the valley carried off great quantities of the soft and easily removed lake deposits originally laid down in the glacial lake, thereby further emphasizing the basin-like form of the reservoir site.

Geologic Conditions Affecting Dams.—The influence of geologic factors in the selection of dam sites is always considerable. A dam project is seldom too thoroughly studied or a site too carefully explored. Frequently, it is taken for granted that conditions are acceptable, which subsequent development prove to be dangerous. Expensive explorations, also, may be made, which intelligent judgment would show were unnecessary.

Studies of the dam sites of the Catskill Project included investigation of the following subjects:

1.—Enough of the geology of the region to be certain that no important geologic influences were overlooked.

2.—Detailed topography over the site and adjacent areas.

3.—Bed-rock contour.

4.—Character of material overlying the rock floor, particularly in regard to porosity and behavior under construction disturbance.

5.—Character of bed-rock. Kind and quality of rock. Condition of the rock with respect to solution or decay or disintegration. Structural features, such as joints, bedding planes, faults, or crush zones. Porosity of the rock and nature of the water circulation, whether through the body of the rock or only along the bedding planes or joints.

6.—Exploration of underground conditions by borings or other means, with directions as to their location and order. Interpretation of boring data with tests of the ground through the borings themselves.

7.—Related questions. Local sources of material for construction, and comparison as to quality and cost, with other available materials. Need of treatment of foundation by grouting or otherwise. Probability of earth movements of such magnitude as to injure the structures. Possibility of claims for damages.

In the selection of a site for the Ashokan Reservoir several locations were investigated. The number of practicable sites was finally reduced to two, the "Olive Bridge" and the "Tongore" sites.

The Olive Bridge Site.—The nature of the drift in the trenches, shafts, and surface exposures of the vicinity indicated that the drift at the Olive Bridge site had been, at one stage in the glacial history of the locality, a natural dam and that water had been successfully held above it to an elevation of 530 ft., and perhaps more. The lowest materials in contact with the bed-rock are heavy stony till, laminated till, and stony laminated clays, all good impervious material making tight contact with the rock, and although a deep pre-glacial gorge lies underneath, at one side of the valley, it is filled with this tight drift and there is no question whatever about its water-tightness.

Sands and laminated clays are extensively developed immediately up stream from the site. These looser materials grade into the heavy till material of the site proper and approach so close that occasional pervious streaks extend well into the westerly edge of the site. They do not at any point extend continuously through this ground, however, and, consequently, the present barrier, as it stands, is practically impervious. On account of the poorer quality of the drift up stream, the dam site was located as far down stream as engineering considerations permitted.

The Tongore Alternative Site.—At the Tongore site, the bed-rock floor in the buried gorge is at least 100 ft. deeper than at Olive Bridge. In the deeper parts, below the 400-ft. elevation, the deposits as indicated by the wash borings, are interpreted as a fairly continuous succession of stony drift, stratified sands and gravels, and laminated sands and clays belonging to two or three different early stages of accumulation. On this material, the heavy upper till was laid down. These overlying deposits are, as a whole, essentially impervious, but the lower 150 ft. will allow ready movement of water, especially laterally. This seems to be indicated also by the rather persistent occurrence of springs and soft wet places along the creek bank at about this level, both above and below the site.

Because of the higher bed-rock at the Olive Bridge site, the more uniform and impervious quality of drift deposits, the more massive cross-section of the barrier of drift on the north side of the site, and the glacial geology connected with the development of these features, that site was considered the preferable location for the dam on Esopus Creek. After the site was selected, the rock beneath the proposed dam was explored in detail by numerous core borings, and the holes were tested for the purpose of locating the position and permeability of seams in the rock. The bearing power and permanence of the bluestones and shales beneath the heavy masonry structure and the possibility of creep of the softer shale members were also investigated.

The Schoharie Development

To complete the Catskill Water Supply System, the Schoharie water-shed is being developed by the construction of the Gilboa Dam which will form the Schoharie Reservoir. From this reservoir, the water is to be diverted

through the Shandaken Tunnel, now under construction, and will flow down the channel of Esopus Creek into the Ashokan Reservoir. Schoharie Creek lies on the north side of the divide from Esopus Creek, in the higher region of the Catskill Mountains. The Esopus flows out of the Catskills through the southerly gateway toward Kingston, N. Y., and the Hudson River, and the Schoharie flows north to the Mohawk River, near Amsterdam, N. Y. The water-shed, 314 sq. miles in area, is similar in character to that of the Esopus, chiefly steep mountain slopes covered with forest growth. The underlying rock consists of sandstones and shales through which the 18-mile Shandaken Tunnel is driven.

Several sites were investigated for the location of a dam on Schoharie Creek. The controlling geological features in the selection of such a site were the relation of a deeply buried inner gorge cut down into bed-rock by the interglacial stream and the quality and structure of the glacial drift deposits above the rock.

The Devasego Falls Alternative Site.—Of all the sites examined, that at Devasego Falls at first appeared to be the most promising from the standpoint of economy, on account of the favorable topography. At this location, a ridge of glacial drift extends into the main valley from the west and seems to have formed part of a dam across Schoharie Creek in late glacial time, causing a lake to form on the up-stream side to the south. The modern stream has trenched through this drift ridge, but at this point it is lodged far to the east side of the valley, where it soon cut into the rock of the valley side and is still cutting in this narrow post-glacial gorge with its inevitable water fall. This is known as Devasego Falls.

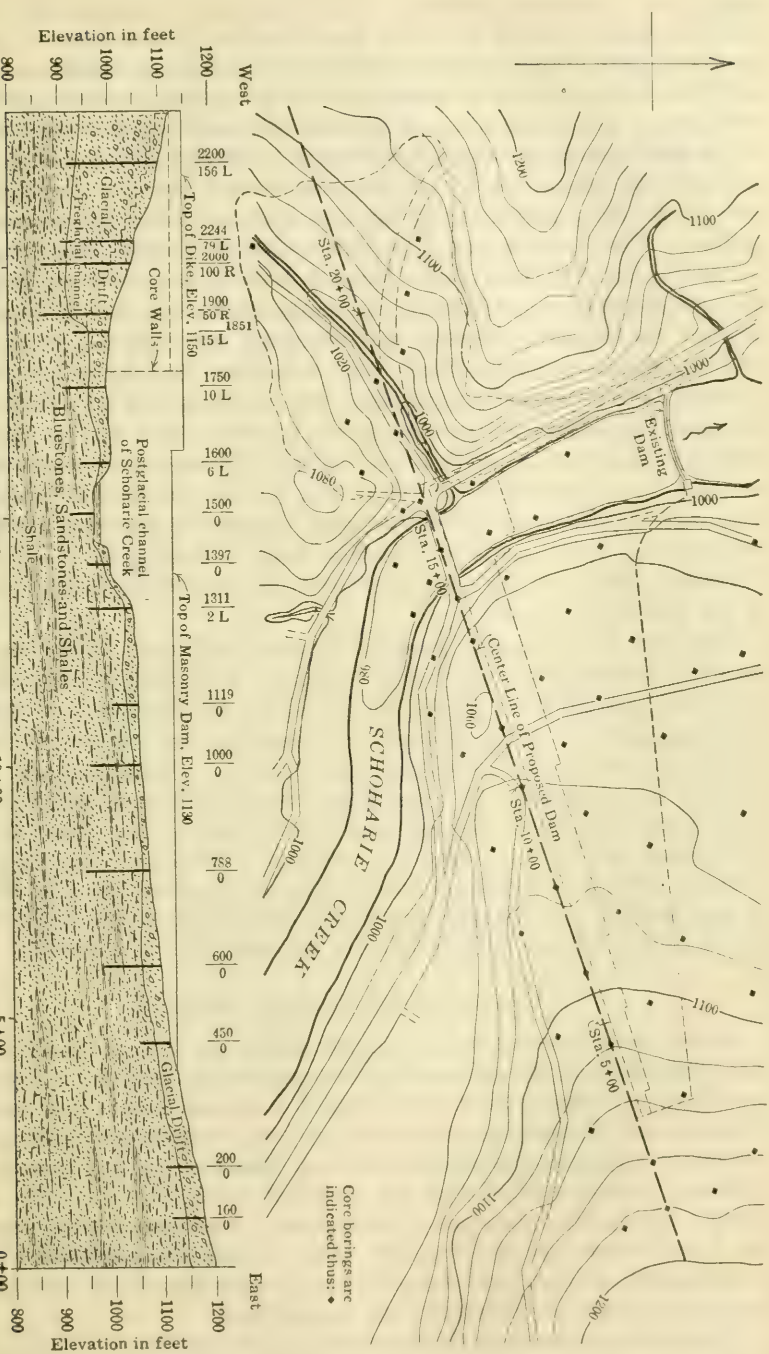
As the stream cut deeper and deeper through the drift obstruction, it drained the lake and has since carried out most of the loose fine sediment which formerly partly filled the basin. This easy erosion, together with the usual tendency to meander where the stream was free, has widened the valley above Devasego considerably, whereas the stream at the proposed dam site had become lodged in a rock cut at one side and the valley bottom was left still heavily obstructed with drift. It was proposed at first to take advantage of this natural barrier of glacial drift, which crosses and almost closes the valley, and to form a reservoir by building a short dam to close the gap made by the modern stream. As the depth of water in the reservoir thus formed would have been nearly 100 ft., the main question was to determine the degree of porosity of the material in the rather narrow drift ridge which would have to retain the water. The ridge is essentially a "kame deposit", formed at the edge of the ice during a melting stage. The material is, in part, transported and assorted and must have been laid down by water flowing from the mass of melting ice, and, in part, it is residual till probably frozen originally in blocks of ice, left to thaw in their present position. The whole is capped by impervious clay, a remnant of the later lake deposit. Formerly, the clay was undoubtedly much more extensive, constituting the topmost beds formed in the standing waters, but the stream has carried it nearly all away, except on top of this protected ridge.

It was anticipated that the mixed materials deposited by both water and ice would be in part porous and in part impervious. This condition was found on examination of the dry samples taken at frequent intervals in the borings. Furthermore, the sandy, porous material and the dense, impervious parts of the ridge were found to lie in no regular relation to each other. At first, it was hoped that these materials of different qualities might be so interlocked and so limited in lateral extent that no strata of porous material would extend continuously through the ridge. It was observed, however, during the drilling operations that the behavior of the ground-water was unusual. The water-table was very low and did not maintain even the general elevation of Schoharie Creek on the up-stream side of the ridge. There was also a tendency to lose water below the water-table as freely as above it. As the imperviousness of the ground was a vital factor, it was decided to investigate further the porosity of the material and the underground circulation by pumping tests. For this purpose, the casings were left in many of the holes. Water was pumped into one hole continuously for a period and the rise in the water was noted in the other holes. Prior to testing, the casings were all lifted from the rock floor to the first pervious layer, as indicated by the original records of each hole, and as the casing was raised the space was plugged with clay. This prevented water from escaping down to and into the rock which was badly fissured. Water was then pumped into a centrally located hole, and the position of the water-table in the other holes was ascertained by soundings.

The geological sections previously developed by the borings had indicated certain pervious zones, and the results from the pumping tests confirmed the existence of these zones and, in addition, made it possible to trace them more or less successfully either to their limits or, at least, to establish their continuity. In general, a broad and extensive pervious zone, 1 000 ft. wide, 1 200 ft. long, and 30 ft. thick, the top of which is about Elevation 1 100, was found to extend in a northwesterly direction, reaching through the ridge to the under strata of the Beaverkill. As a result of this investigation, and for the additional reason that investigations at the alternative site at Gilboa have shown decidedly better conditions there, the Devasego site was definitely abandoned.

The Gilboa Dam.—After investigating several favorable locations on Schoharie Creek, it was decided to locate the dam at Gilboa, N. Y., and create a storage reservoir in the valley of that stream. A line of borings across the valley showed that bed-rock on the east side of the river is thinly covered with glacial drift and slopes gently to the west, and that the west side of the valley is filled with compact glacial till which fills the pre-glacial bed-rock gorge with impervious material. Although here, also, there is a much deeper old rock gorge beneath the drift of the west side of the valley, the natural obstruction now filling it, represented by the clay and till, is so effective a barrier that advantage can be taken of it in constructing the dam.

At Gilboa (Fig. 5), just as at Olive Bridge on Esopus Creek, the present stream flows in a new rock channel in the side of the valley, made since the ice of the glacial period withdrew, and the old channel is buried under a



SCALE IN FEET
100 0 100 200

GEOLOGIC SECTION ON CENTER LINE OF PROPOSED DAM

FIG. 5.

great load of compact material. This is the ideal location for a dam in glaciated regions, but it is seldom that better conditions, even of this kind, are found than those presented at Gilboa. To meet the conditions, the dam at Gilboa will consist of a masonry section of Cyclopean concrete founded on rock in the present stream and the east end, and will join the till barrier of the west bank by means of a substantial earth dam with a core-wall deeply seated in the compact earth. As the form of the valley is a deep and narrow trench, the masonry section of the dam will be constructed as an over-fall spillway. The down-stream face will be made in large steps faced with natural stone. The face of the Ashokan Dam is formed of concrete blocks. The durable bluestone bed-rock of the gently sloping east bank will be stripped to form the over-flow channel, and the water will thus flow down the dip slope of the beds, parallel with the face of the dam, discharging into the gorge.

At the several quarries investigated, there are beds, 2 to 3 ft. thick, suitable for supplying blocks for the facing of the dam. In a general way, all of them are more quartzose than the average bluestone and some, therefore, are more nearly related to quartzites than to the simpler bluestones such as were used for the blocks in the Cyclopean masonry of the Olive Bridge Dam. There are no constituents that readily decay or develop stain or are likely to exhibit weakness. The mineral composition is as stable as the constituents of the best types of rocks.

The rock has a roughly granular structure and undoubtedly was a very granular accumulation when it was deposited. Microscopic examination, however, discloses that many of the original grains are fragments of rock rather than fragments of simple minerals, and therefore are complex in their own structural make-up and mineralogy, each fragment containing quartz, sericite, and sometimes chlorite. This fact makes the rock look more complex than the usual sandstone, but all the fragments are of durable, firm materials and no detrimental quality is introduced by the fact of their complex structure. It would be difficult to find better rock for exposed structures than the bluestones of the Catskills. Even a granite resists weathering no better, and some varieties of granite, because of their different structure, are not as durable.

Location of the Catskill Aqueduct

In the early investigations of a water supply for New York City, sources east of the Hudson River, as well as the ground-waters of Long Island, were considered. As these studies were extended, it became evident that the streams of the Catskill Mountains were the best available sources. A storage reservoir site of great promise was shown to exist at Ashokan, and rather early in the studies it became evident that the aqueduct must start from the Ashokan Basin. The problem was one of conveying a large quantity of water from the Esopus water-shed to New York City. It was also necessary to develop a considerable storage basin near the city, on the line of the aqueduct, and, for this, the Kensico Reservoir site was selected.

The region traversed by the aqueduct may, for convenience, be divided into the following districts:

(1) The elevated easterly margin of the Catskill Plateau, extending from the Ashokan Reservoir to the Rondout Valley;

(2) A part of the Great Appalachian Valley, extending from the Rondout-Esopus border of the Catskill Mountains to the Highlands of the Hudson;

(3) The mountainous Hudson Highlands;

(4) The Piedmont region of Westchester County, south of the Highlands, extending to Long Island Sound; and

(5) Part of the Coastal Plain, represented by Long Island.

Each of these types of country presented problems peculiar to its own structure and history, so that a great variety of factors is involved. The type of structure selected and economy required that as much of the aqueduct as possible should be constructed on the hydraulic grade, but where the country rises above the hydraulic grade, it was clear that such heights must be penetrated by tunnels at grade, whereas valleys or depressions could be crossed by pressure tunnels at considerable depth in sound rock.

Geologic Features Affecting Location.—The geologic factors entering into the location of the aqueduct take into account such large features as the structural basis and origin of the topography with its variety of relief forms, modifications of drainage, and changes in topography due to glaciation, the general structural trend of the formations, with their attendant folds, faults, joints, cleavage, and the general physical condition of the rocks of the region. All these geological factors contribute to an understanding of the present and former topography and the general rock condition and behavior of the ground. They affect, therefore, the general problem of location. For example, the Tertiary peneplain in its gradual descent from the inland country toward the sea practically fixes the hydraulic grade across the broad tracts bordering the Hudson River. In like manner, the trend of formational structure is in direct control of the courses of the valleys and ridges, and thus, also, governs the choice of possible courses the aqueduct might follow.

The first aqueduct route to be investigated began at the east end of Ashokan Reservoir near West Hurley, N. Y. Shortly after this line was surveyed, detailed studies showed that a change in the outtake of the reservoir from the location studied near West Hurley at the east end to a point near the Olive Bridge Dam had certain advantages in the operation of the aqueduct. In addition, the shifting of the line farther west made available certain topographic features favorable to its location. Investigations by borings in the Hudson River near New Hamburg, N. Y., early established the fact that the rock gorge there is very deep. Furthermore, on the New Hamburg route, a crossing of the Hudson Valley from the vicinity of Marlboro, N. Y., to the Highlands near Fishkill Village, would have required a pressure tunnel about 9 miles long, penetrating the limestone beneath the river. The uncertainties of behavior of the limestone under such conditions early led to suspicion of all lines along which these dubious formations were prominent. In addition, several faults would have to be crossed by such a tunnel, and it was believed that some of them might prove to be troublesome either in construction or maintenance. Consequently, attention was called to the possible advantages of crossing the stream between Storm King and

Anthony's Nose where the old crystalline rocks of the Highlands assured a much firmer medium for a tunnel and the avoidance of most of the uncertainties and known difficulties of the New Hamburg route.

Choice of the Storm King Line.—The work of exploration was finally concentrated at Storm King on the northern margin of the Highlands, where the river was narrow, the rock sound, and the conditions generally favorable for deep shafts. Preliminary to the adoption of this location, four lines were investigated, namely, the Storm King, the Little Stony Point, the West Point, and the Anthony's Nose line.

The objection to the Anthony's Nose line was that a large part of the route through the Highlands would be in tunnel, with several deep shafts, in places far back in the hills difficult to reach, with a long pressure tunnel beneath the river itself. On the West Point line, although the river is only 2 100 ft. wide, the distance between hydraulic grade points is 1.6 miles. Furthermore, a wide crush zone and a belt of ancient limestones are believed to lie beneath the river, which was judged to be less favorable for tunneling than a more substantial rock. The Little Stony Point line had the disadvantage of requiring some cut-and-cover on the west side of the river, in glacial drift, along an exceedingly steep mountain side, where land slides of soft material might endanger the stability of the aqueduct. On the route finally chosen at Storm King, the river is 2 900 ft. wide, with excellent rock on both shores. Favorable and accessible shaft sites near the edge of the river were an important advantage in this location, and the "cut-and-cover" country on the east side of the river through Breakneck Valley made for additional economy. The determination of the depth to bed-rock under the river was a critical problem by any route, as that depth would control the depth of the pressure tunnel. It thus became practical to concentrate work at a definite point so that this investigation could be made. Boring operations for this purpose, in the gorge of the Hudson, were carried on for about two years. This location is described subsequently in more detail.

After the Hudson River crossing was once established, the route to the south of it became fairly well fixed, the first objective being Kensico Reservoir and the second one, Hill View. The controlling features were the topography of the region and the economy of the project. No sufficiently objectionable conditions were found to warrant great changes of course after it was once laid out. South of Hill View, however, within New York City proper, many alternatives were presented, which required detailed study and exploration. This part, which is known as the City Tunnel, is discussed subsequently in more detail.

Cut-and-Cover Aqueduct South of Ashokan Reservoir

From the main head-works of the Ashokan Reservoir at Brown's Station, N. Y., the aqueduct follows the post-glacial valley of the Beaverkill, along a drumlin, as a cut-and-cover structure as far as the gorge of Esopus Creek which cuts at right angles to the course of the aqueduct. On the north side of this gorge, a boring was made to determine the depth to the bluestone ledge, which outcrops in the stream bed and across the valley of the creek to the south.

It was expected that this valley would be crossed by a pressure tunnel deep in the rock, but as the borings in the north bank showed that the bed-rock was deep and sloped downward to the north beneath the drift hills into the buried gorge of the pre-glacial Esopus, the plan for a tunnel was abandoned, as the down-take shaft would be in earth to a prohibitive depth. A steel pipe siphon, therefore, was adopted instead of a tunnel in rock, for the crossing of the Esopus trench.

An inspection of the topographic map, particularly at Elevation 500, shows that the south side of the Esopus Valley, for a distance of several miles south of Ashokan Dam, is much smoother and less broken by tributary gullies than the north side. This difference is due largely to the effect of glacial action in smoothing the south bank in the southwestward movement of the ice during the main ice advance, whereas the roughness of the north bank is due to the gullying action of the glacial waters discharging from the northeast into the Esopus gorge in the retreat or melting stage of the ice. Because of this greater smoothness of contour, the south side of the valley was chosen for the location of the aqueduct. The only considerable depression on this line for several miles is the gully of Tongore Creek near Davis Corners, N. Y., where a pronounced trench is cut in the glacial till by waters discharging from the drift-filled valley to the southwest. It was crossed, as in the case of Esopus Creek, by a short steel pipe siphon.

At the "Atwood Cliffs", still farther south, the aqueduct was carried along the face of the precipitous escarpment for 900 ft. with a deep cut in the rock. In the much jointed, horizontally bedded shales and bluestones of the Hamilton, which form the bed-rock in this section of the line, it was found that the explosives used shattered the rock so badly that the trench broke wider than had been expected, thus increasing the work involved, particularly where the surface material was affected considerably by weathering.

Peak Tunnel was driven through the bold hill at the point of leaving the Esopus Valley, thus making a short-cut course to the much more smooth country along the edge of the Hamilton escarpment which forms the westerly margin of Rondout Valley. For the cut-and-cover portion south of Peak Tunnel, hard, well compacted, glacial till was encountered, which was successfully excavated to the narrow base and steep slopes prescribed, effecting a material saving over the wider trench in the horizontally bedded and weathered rock north of Atwood, N. Y. At the southeasterly end of this stretch of cut-and-cover construction, the Rondout Valley is reached, and a pressure tunnel in bed-rock was adopted for this crossing.

General Considerations Relating to Design of Pressure Tunnels

Of all the types of aqueduct, the pressure tunnel was, perhaps, given the most study, as there was no precedent for tunnels operating under such high heads. Pressure tunnels had been used to some extent, but none of them was subjected to an unbalanced head much greater than 100 ft., whereas on the Rondout Pressure Tunnel the unbalanced head is about 400 ft. and the ground-water head on the Hudson Pressure Tunnel is 1 100 ft. when the tunnel is empty. The pressure tunnels are designed with vertical waterway shafts and a tunnel deep in the rock to carry the water from one side of the

valley to the other. The strength and water-tightness of the rock is mainly depended on to retain the water without undue loss. The tunnel excavation, which is circular in form, is lined with concrete, to serve not only as a support to the rock and to provide a high coefficient of flow, but also to obstruct the escape of water from the tunnel. This last function of the concrete is aided by grout, which was forced under high pressure into all openings between the concrete and the rock and also into all water-bearing joints and porous openings of the rock itself, within reach of the operation. The concrete lining, therefore, supplemented by the grout filling of all adjacent spaces is depended on to make a reasonably water-tight conduit. The advantages of this type of construction may be enumerated as:

(1) Great permanence;

(2) Very low maintenance cost;

(3) Cheaper original cost than any other equally efficient conduit; and

(4) Convenience in operation.

The last two considerations may be illustrated by the 18 miles of pressure tunnel in New York City where sixteen lines of large diameter steel pipe would have been required to carry and distribute a supply equivalent to the single pressure tunnel.

Permanence is a matter that has been most carefully considered. In the case of other pressure tunnels where relatively low pressures have been used, the rocks are stable and little disturbed by folding and faulting. In the country traversed by the Catskill Aqueduct, serious local movements have disturbed the strata, but the rocks are generally of such an insoluble and permanent character that there is little fear of their deterioration. This sound character of the rock is a decidedly favorable condition. It appears also that the lower New York region is now comparatively stable as compared with most of the Rocky Mountain or Pacific Coast regions. One must recognize that movement might occur here, or for that matter anywhere else; but few known regions have so little evidence of recent disturbance as this, although in an earlier period such movements were common and extensive. Some of the most important effects of these earlier disturbances may now be seen in the faults and crush zones encountered in many places. At such points, the rock is much weaker than usual and is also less stable during and after construction, and, furthermore, it is believed that if a new movement should affect the region, it would be likely to follow some of these old weaknesses. Therefore, the line with the fewest known faults is the most desirable, not only because of the wish to avoid bad ground, but also because of possible further shifting.

In order to prevent bursting of the tunnel subjected to high pressures, which would result in leakage and loss of water, it is essential that the rock be strong enough to meet the severe demand made on it. Therefore, a proper understanding of the condition of the rock became of prime importance. Zones of disturbance, or decay of the rock, and zones of weakness induced by deformation were carefully considered. It was deemed to be very important to place the tunnel at an adequate depth beneath the surface of sound rock in order to escape the influence of superficial weaknesses. There-

fore, in all cases, a cover of not less than 150 ft. of sound rock was provided, except for comparatively light heads.

The circular shape was adopted for pressure tunnels and permanent shafts, because of the external pressure to which they may, in places, be subject when the tunnel is under construction or out of service. The pressure from ground-water depends on the relative porosity of the rock and the concrete. Thus, with a tight lining and porous rock, the lining would receive nearly the full ground-water head; whereas, with a tight rock and an equally impervious lining, the lining would get little pressure. It was thought that porous or seamy rock would be made tight by grouting and that the rock itself would constitute the main reliance against inward or outward leakage. The lining of the tunnel was made of such thickness as to withstand the static ground-water head and the grouting pressure, and the grouting of all openings back of the concrete lining was depended on to cut off outward leakage. This provision is very important, as water can escape wherever it can enter a tunnel and in much greater quantities, because the unbalanced heads producing outward flow from the full aqueduct under pressure are much greater. Ground-water pressures of 200 to 475 lb. per sq. in. have been measured by means of gauges applied to grout pipes in the tunnels.

The Rondout Pressure Tunnel

The comparatively low Rondout Valley is crossed by a pressure tunnel 4½ miles long, which was driven from eight working shafts about 500 ft. below the general floor of the valley. The tunnel has an inside diameter of 14½ ft., and the concrete lining averages 22 in. in thickness. The excavation averaged about 10 cu. yd. per lin. ft.

Summary of the Rondout Problem.—The main problem presented in the study of the tunnel location related to the proper depth of the tunnel in the rock, which, in turn, was influenced by the location and depth of the pre-glacial drift-filled gorges, and the attitude of the several rock formations penetrated, especially the location, thickness, and inclination of the Shawangunk grit with reference to its intersection by the tunnel. General studies and explorations, made to determine the choice of tentative lines crossing the valley at a number of places between Hurley and High Falls, showed that the geological formations at the location chosen were less disturbed by folding and faulting than at any other part of the entire valley, and other considerations made the High Falls location the most desirable. A comparison of the cost of rock tunnels with the cost of pipe lines and other structures, showed the tunnels to be the cheapest, even with shafts more than 1 000 ft. deep and allowance for special construction in case unusually bad ground should be encountered.

Earlier exploratory borings in the valley at Hurley revealed the rock in the bottom of the same ancient valley at a depth of 70 ft. below sea level, and showed that it is overlaid by a layer of sand about 220 ft. in thickness. This valley, following the Hamilton escarpment along the easterly margin of the Catskills, is bottomed by the Onondaga limestone. The line was finally moved several miles farther south, beyond the reach of the Esopus proper,

where a much heavier drift cover badly obscures the topography of the rock floor. From a study of the outcrops, applying the recognized principles of erosion effects on dipping strata, it was expected that the borings on the crossing at High Falls would discover a gorge in a corresponding position along the westerly margin of the valley at the border of the Hamilton flag formation. This was indeed the case. In addition, another gorge was disclosed by the borings near the middle of the valley, deeply buried, and so masked by deposits of glacial drift that its existence is not indicated in the present relief.

The first general geological cross-section of the valley, however, based on surface indications, was a fairly close approximation to the structure finally developed in much more detail by the borings. Two buried pre-glacial stream gorges, and the fact that the rock in places was broken by faulting and was porous, controlled the depth of the tunnel. Near the east end of the tunnel, also, a fold involving the very hard Shawangunk grit made it desirable to place the tunnel so deep that it would pass beneath the grit and lie entirely in the more easily excavated Hudson River shale below.

The geologic complexity of this valley is due chiefly to the number and variety of rock formations, including many beds of limestone, shale, and grit, and to their folded and faulted condition. On these strata of different resistances to erosion, a topography consistent with the detail of the structure has been developed. Where the more indestructible beds, such as the Shawangunk grit occur, there are ridges, and where the less resistant beds form the floor, erosion has cut deeper and there are valleys. The relief features of the rock floor, chiefly erosion channels, represent the work of streams due to the uplift preceding the Ice Age. These minor features, however, are much obscured by the drift. It is these later channels, especially their great depth, that became critical factors in determining the depth of the tunnel. The following formations are penetrated by the Rondout Tunnel, the Hamilton flags being at the top on the west side of the valley, and the Hudson shales, the lowest of the series, being on the east side of the valley:

	Thickness, in feet.
Hamilton flags and Marcellus shales	700
Onondaga limestone	200
Esopus gritty shales	800
Oriskany sandstone (not separately developed)	...
Port Ewen shaly limestone, including the Oriskany transition	200
Becraft crystalline limestone	75
New Scotland shaly limestone	100
Coeymans limestone	75
Manlius limestone, including the Cobleskill, and the Rosendale and Rondout cement beds	100
Binnewater sandstone	50
High Falls shale, including thin limestone layers	75
Shawangunk conglomerate	300
Hudson River slates, thickness unknown, probably more than	2 000
Approximately	4 775

Factors Affecting the Tunnel Grades.—The tunnel profile was fixed by the following requirements:

(1) To pass beneath the buried Kripplebush Gorge, at the west side of the valley, with a sufficient rock cover;

(2) To pass safely under the buried Rondout Gorge, near Station 500, in the center of the valley;

(3) To avoid, as far as possible, the Shawangunk grit, in the Coxingkill syncline, at the east side of the valley;

(4) To pass through the porous Binnewater sandstone in as short a distance as possible;

(5) To drive up-hill at a high angle through the heaviest water-bearing members for the purpose of draining the water away from the heading;

(6) To avoid driving up-hill on grades of more than 2% where lower grades are possible; and

(7) To have the entire tunnel drain toward the sump at the drainage shaft near Rondout Creek.

These requirements were met by placing the northerly half of the tunnel at Elevation — 100 in the vicinity of the most porous strata. There, a 15% incline through the wet ground connects with the southerly half which was put at Elevation — 250 so as to keep the tunnel below the Shawangunk grit and in the Hudson River shales.

Question of Solubility of Limestones.—The question of the possible solubility of the limestones was considered with great care. Certain caverns, due to the solution of these limestones, can be seen at the surface, and others were indicated by the borings, and it seemed not improbable that many solution channels may have been formed in earlier times to considerable depth in both the Onondaga and the Helderberg limestones. Fig. 6 is a view in the Rondout Siphon Tunnel, which shows the solution effects on bedding planes of Helderberg limestone, causing wild breakage at "mud seams", requiring 7 ft. of concrete in the roof.

If these limestones, which have proven to be soluble when exposed to ordinary meteoric water circulation, should yield in the same way to the tunnel waters, not only would the concrete lining be subject to disintegration, but the supporting rock immediately outside of them might be, in part, removed and the escape channels enlarged, seriously increasing the loss of water from the tunnel. These considerations led to the tunnel being placed below the zone most affected by surface-water circulation, avoiding as far as possible the most susceptible strata. It led also to the rejection of limestone aggregate in the concrete lining.

Factors Affecting Construction.—Under the subject of design, the general condition of the rocks of this region and their structural relations have been discussed. The hard or soft character, porous or fractured condition, and resultant permeability, the chemical changes to which they have been subjected, all have a bearing on the methods of tunnel driving and the design of tunnel adopted. Although the rocks are mostly hard, durable, and sound, the earth movements to which they have been subjected have resulted in the

formation of folds, joints, occasional faults, and crush zones. Such conditions may result unfavorably by causing an unsafe roof in places, requiring scaling or the use of temporary wooden timber or even permanent steel roof support. In other cases, small folds or intersecting fracture planes produce blocky and caving ground. In the soluble limestones, the circulation of underground water tends to dissolve parts of the beds and to produce openings by the enlargement of joint planes, with the result that the rock is weakened and, in places, cavernous. Conditions such as these required enlargement of the excavation in unsound rock, reduced the speed of excavation and the placing of concrete, and, in a few places, introduced an added cost for steel or timber roof support.

Since the lining has been placed, an opportunity has been given to observe the effect of ground-water on the concrete. The concrete shows no tendency to deteriorate and tests of the aqueduct in service have shown the pressure tunnels to be tight against outward leakage.

The Rondout Pressure Tunnel affords a good illustration of the influence of underground conditions on the progress of tunnel work. Fig. 8 is a progress diagram of the Rondout Tunnel and illustrates the influence of adverse geological conditions on the progress of the work. Where the rock was fairly uniform in quality, as in the shales and limestones, rapid and consistent progress was made in excavating, the average progress in these rocks being 350 ft. per month. Because of the hardness of the rock, the progress in driving through the Shawangunk grit was much slower, averaging 160 ft. per month. The longest delay in the construction of this tunnel was at Shaft 4 and in the tunnel between Shafts 3 and 4. The difficulties there were due to the large inflow of water in the Binnewater sandstone and High Falls shale. Shaft 4 was flooded several times and the sinking of it was delayed about a year on account of the troubles caused by water. An account of the sinking of this shaft has been given in a paper* by John P. Hogan, M. Am. Soc. C. E.

The large mud seams and broken cavernous ground encountered in excavating the tunnel south of Shaft 3 necessitated special methods in driving and lining. Special provisions were made there for reinforcing the tunnel with a steel shell. These extra precautions and the provisions made for curing the natural weaknesses caused much additional delay. Hydrogen sulphide gas in the Binnewater sandstone and High Falls shale made it difficult for men to work, as their eyes were affected by the gas, and to remedy this trouble, ventilation by blowers was provided. The acid water and gas also attacked the switchboard equipment of the electric pumps, making special protection necessary.

Fig. 7 is a view in the Rondout Pressure Tunnel, which shows the wet ground encountered in the High Falls shale and the Binnewater sandstone where these rocks were penetrated by the tunnel at the overthrust fault near Shaft 4.

Although the water-bearing beds on the incline gave so much trouble, most of the water entered in a stretch only 175 ft. long, half way up the incline

* "Sinking a Wet Shaft", *Transactions*, Am. Soc. C. E., Vol. LXXIII (1911), p. 398.

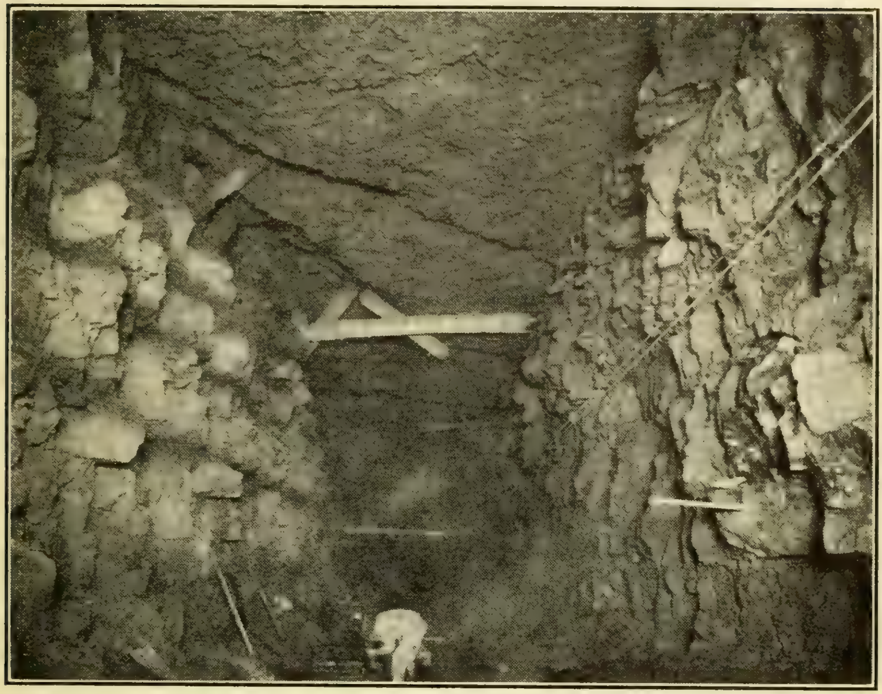


FIG. 6.—VIEW IN RONDOUT SIPHON TUNNEL, SHOWING SOLUTION EFFECTS ON BEDDING PLANES OF HELDERBERG LIMESTONE.

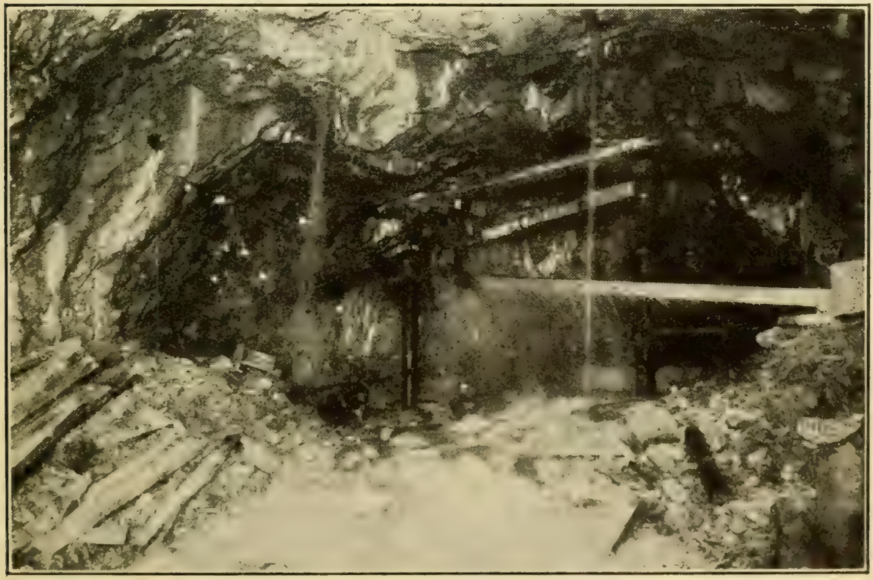
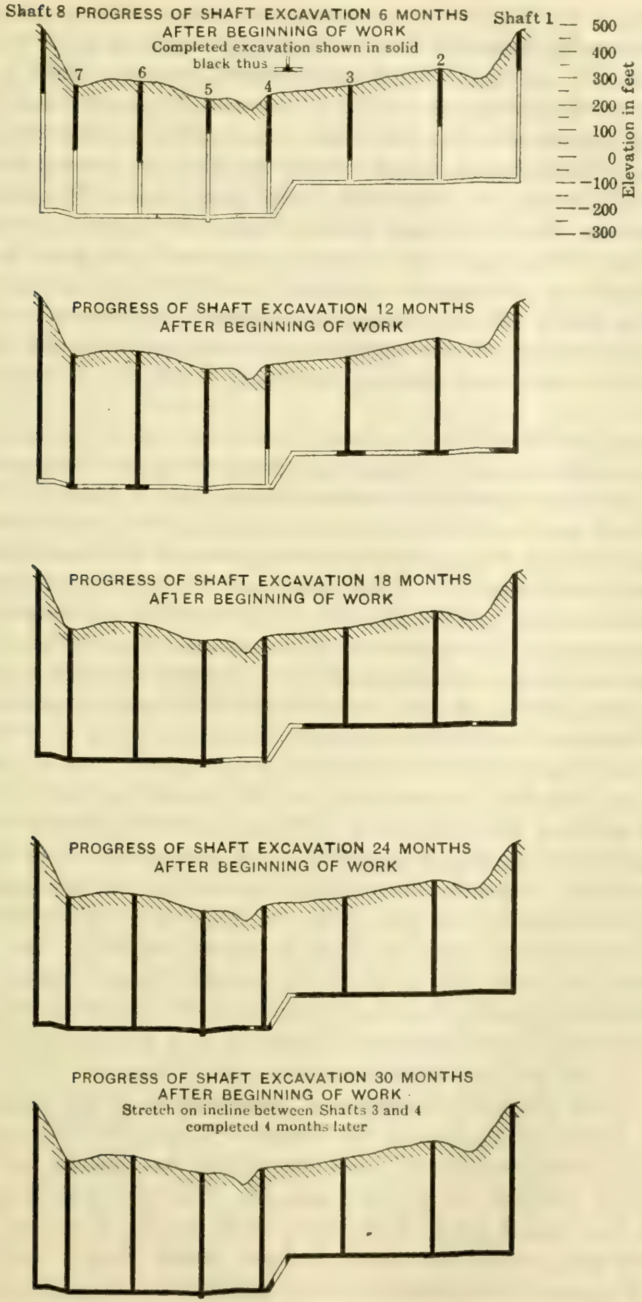


FIG. 7.—VIEW IN RONDOUT PRESSURE TUNNEL, SHOWING WET GROUND IN HIGH FALLS SHALE AND BINNEWATER SANDSTONE.



DIAGRAMS SHOWING PROGRESS OF EXCAVATION
RONDOUT PRESSURE TUNNEL

The slow progress in sinking Shaft 4, and in excavating the Tunnel between Shafts 3 and 4, was due to (1) The excessive quantity of water encountered, (2) the effects of H_2S Gas and (3) the Crushed and Broken Ground Penetrated in the Tunnel

FIG. 8.

in the High Falls shale, where these beds were much distorted along a strong thrust fault which seemed to furnish the way of escape for all of the overlying porous beds. To prevent outward leakage from the tunnel which is subject at this point to a head of about 700 ft., the concrete lining was made 3 ft. thick. This lining was placed inside a steel shell to protect the concrete during placing and setting. Dry packing placed outside the steel was grouted and the surrounding porous rock was impregnated with grout under high pressure. The water entering the tunnel just before closing all leakage in this stretch amounted to 1 000 gal. per min. Ground-water was drawn down to Elevation — 55, and after all pumping was stopped, it took 40 days to restore it to Elevation + 65, a rise of 120 ft., representing a volume in the tributary underground reservoir of 64 000 cu. ft. per vertical foot. In the earlier stages of construction, the inflow was much heavier, reaching a maximum of about 1 900 gal. per min.

Although 250 000 cu. yd. of solid rock was excavated in driving this tunnel, none was suitable for concrete aggregate except the grit. Two quarries were opened in the Shawangunk grit outcrops situated east of Rondout Creek, making long hauls necessary in transporting the crushed stone to the several shafts. The rock excavated from the tunnel was examined by the geologists, who investigated the permanence of the stone used in the concrete lining of the deep tunnels and the possible solution or disintegration of the material composing the concrete. Their conclusions are summed up as follows:

The pressure tunnels are necessarily the weakest links in the whole Catskill System. They present not only special difficulties in construction, but they will be continuously subjected to greater strain by reason of pressures, and greater attack from the solvent action of water than other parts of the aqueduct line. If the work is to be permanent or even reasonably durable, every consideration affecting the matter as a public enterprise of importance is on the side of caution in the use of materials. This applies with most force to the pressure tunnels. Not only is it injudicious to use stone of uncertain or doubtful resisting quality, but, in view of the fact that others of safe character are available, such action would be open to severe criticism. The additional expense involved in the use of the better material would amount to such a small proportion of the whole cost as to lose much of its seeming importance.

The weak shales were condemned because of their low strength and marked tendency to dry out and crumble on exposure to the air. The limestones, although strong and hard enough, were considered as too susceptible to solution. Of all the formations in the Rondout Valley the Shawangunk grit, because of its hardness, strength, and insolubility, was regarded as the best of the local rock available for concrete material. The cost of drilling this very hard rock was high, because of the wear on the drills. The rock is strongly bound, and came out of the quarry in large masses, jagged and difficult to handle. The wear on the manganese steel crusher parts exposed to the cutting action of the hard quartzites was great, and renewals were frequent.

Failure of the Rock Under the First Hydrostatic Test.—After the tunnel had been completed, and the construction shafts sealed with concrete plugs,

the tunnel and end shafts were filled with water and subjected to the working pressure. Under this test the concrete lining was ruptured for several hundred feet between Shafts 3 and 4, making repairs necessary.

The tunnel lining had been cracked where the cavernous ground in the Helderberg limestones had been encountered, and also on the incline in the Binnewater sandstone. The limestones in particular had been weakened by solution along joints and bedding planes. These caverns and mud seams are not isolated, but are doubtless connected and irregular, following the pattern of the original joints. Evidently, the pressure in the tunnel had overcome the resistance of the surrounding rock, which was not everywhere solid and continuous, but in effect had become, in some places, a series of blocks separated by soft and yielding clay. It was necessary, therefore, to repair the damage and make the tunnel water-tight. Steel shells had been used originally at certain points of well recognized rock weakness, and at none of these places was there any movement or damage. Accordingly, it was decided to repair about 700 ft. of the cracked tunnel in a similar manner. This was done in three stretches by reinforcing the lining with a steel shell about 1 in. thick, made up of rings composed of 15-in. channels with their flanges riveted together. The cracks in the rock caused by the movement of the ground were then grouted under high pressure, to prevent the escape of water. This repair was successful and no further difficulty has developed. When the tunnel was designed, the possibility of such failures was recognized, but it was thought better to discover points of weakness by test, and to strengthen those parts that required it, than to reinforce all parts of the tunnel about which there might be some question.

The Wallkill Valley

From Shaft 8, the terminus of the Rondout Pressure Tunnel at the western slope of the Shawangunk Mountain, the aqueduct pierces the mountain about Elevation 450 by a tunnel which is driven in the easily excavated Hudson River shale beneath the cap of hard grit covering the north end of the mountain ridge. This tunnel emerges below Bonticou Crag on the east slope at a favorable point for a portal. A tunnel through this mountain at any other location would have been much longer, or would have encountered the resistant grit bed, in either case greatly increasing the difficulty of driving and the cost.

Freer Cut.—On the eastern slope of the Shawangunk Mountain (Fig. 9), where the rock ledges are sparsely covered by glacial drift, the aqueduct follows the contour southward at grade for a distance of 4 miles. Here, the excavation encountered the shales of the Hudson River series which were excavated rapidly and cheaply by blasting and steam shovels, except in the deep Freer Cut, where difficulty was encountered through a stretch of 2 000 ft. The strike of the rock formation here is nearly parallel with the center line of the aqueduct and the dip is about 40° in the direction of the general eastward slope of the mountain. (Fig. 10 is a view of the cut-and-cover aqueduct in Freer Cut, in the Hudson River shale, which shows wide breakage due to the dip of bedding planes at the west (right) side (1:1 slope). Note the steep slope (6:1) of the cut on the opposite side).

Trouble was had from the beginning on the west side of the Freer Cut by the sliding of the rock on its bedding planes. As the cut increased in depth, the shale slid down in great masses into the cut, burying the track and steam shovel. The right or east side was self-sustaining, because the dip of the beds on that side was away from the excavation. The greatest single slide amounted to about 2 000 cu. yd. of rock. Because of the great widening of the cut on the west side by these slides, it was necessary to re-locate the aqueduct structure after the excavation had been in progress for some months, moving the center line to the east so as to keep the excavation within the property lines of the city. The contractor's railroad for the stone supply from the quarry at Bonticou was also affected, and was rebuilt for a distance of several thousand feet. The conditions at Freer Cut increased the excavation from an estimate of 85 000 cu. yd. to 155 000 cu. yd. actual, besides requiring a substantial modification in the design of the concrete structure, in order to avoid possible damage.

Geology of the Wallkill Valley.—The Wallkill River is a striking example of a retrograde stream. It flows northeasterly from its source in New Jersey a total distance of about 75 miles in a direct line, to the southward-flowing Hudson which it joins at an obtuse angle. This fact alone is sufficient to indicate that its present channel is composite, and that a part of the drainage has been reversed in comparatively recent geologic time. A reversal of the drainage means that the modern river is at some point flowing across a former divide or water-parting; and the approximate location of this divide, if it is not too far from the normal course of the aqueduct, is of practical importance, as it would furnish a crossing with the highest possible rock floor and the least gorge development. The determination of the latitude of the buried divide and the location and depth of the pre-glacial gorge were given special study.

North of the New Jersey boundary, the geological structure of the Wallkill Valley is as simple as that of the Rondout Valley is complex, because from this section of the Great Valley, erosion has removed the entire series of Silurian and Devonian strata down to the Hudson River slate and sandstone. On the northwest, the Hudson River slate rises in the steep slope of Shawangunk Mountain capped by the heavy protecting bed of Shawangunk grit. Much of the floor of the Wallkill Valley is referable to the Tertiary base level; but north of New Paltz, N. Y., the immediate or inner valley of the Wallkill, 1½ or 2 miles wide, close to the base of Shawangunk Mountain is sunk below this level. To this inner valley, the Tertiary peneplain holds the relation of a broad uneven terrace stretching between it and Marlboro Mountain to the east. The Hudson River beds are, throughout, strongly folded and characterized by a marked cleavage structure dipping to the east. Throughout the area of the Hudson River formation, there is less agreement between the topography and the geological structure than with the other strata, but even in this series, wherever marked differences of hardness exist, this fact is reflected in the topography.

The absence of much boulder clay in this part of the valley greatly facilitated the making of test borings. South of Libertyville, N. Y., however,

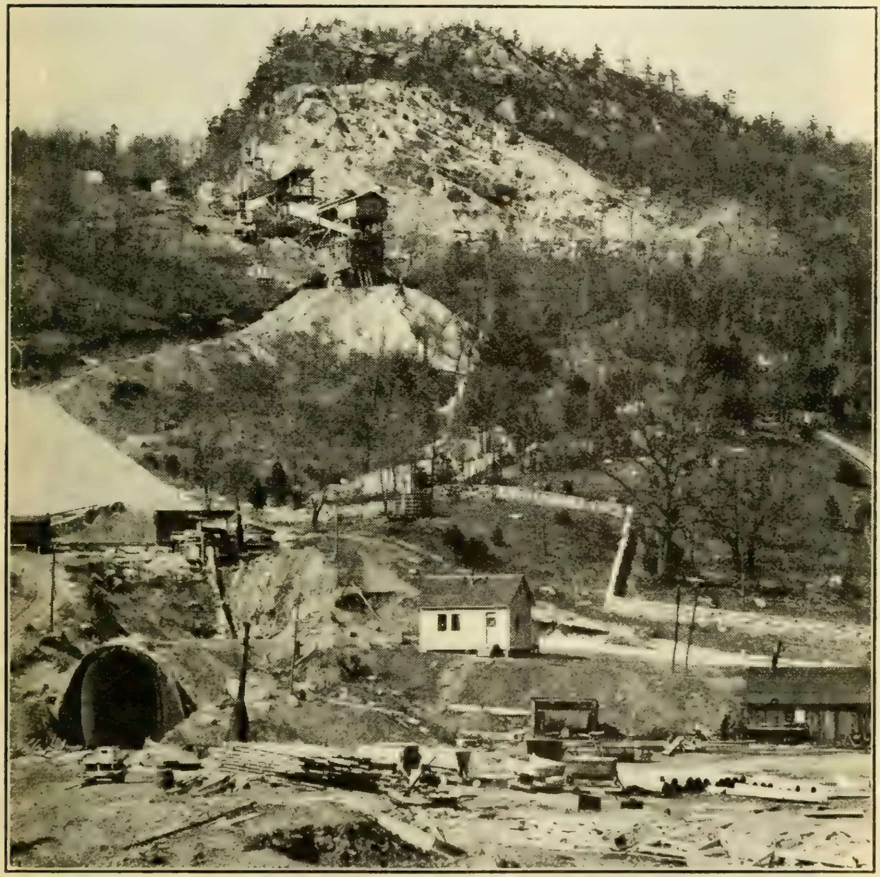


FIG. 9.—RONDOUT PRESSURE TUNNEL EMERGING BELOW BONTECOU CRAG, ON EASTERN SLOPE OF SHAWANGUNK MOUNTAIN.

FIG. 10.—VIEW OF CUT-AND-COVER AQUEDUCT IN FREER CUT.

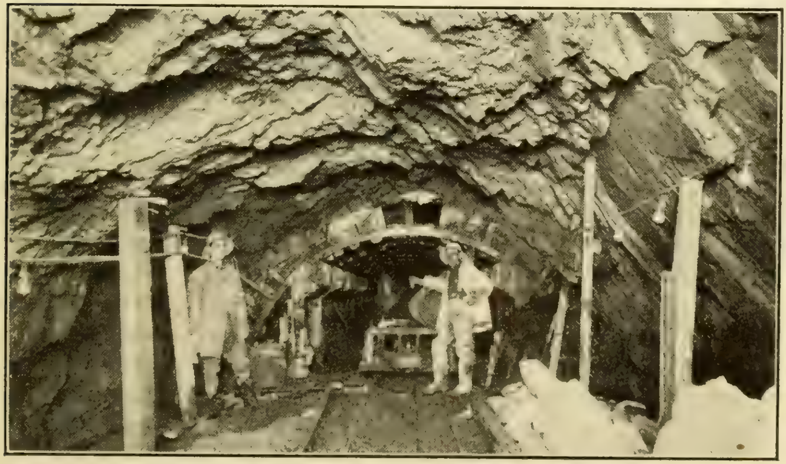


FIG. 11.—VIEW IN WALLKILL PRESSURE TUNNEL, SHOWING STRUCTURE OF HUDSON RIVER SHALE. CONCRETE ARCH FORMS IN BACKGROUND.

the drift is largely boulder clay for about 8 miles, to the vicinity of Walden. N. Y. The favorable character of the Hudson River shales for aqueduct tunnel construction was always recognized, because of the sound unweathered condition of these sandy mudstones. Although folded and faulted considerably, they are largely self-healing and tight, even along zones of strong movement. Almost the only purpose of the borings was to determine the position of the bed-rock floor and the depth and position of the buried pre-glacial channel of the Wallkill. The first and most northerly line of borings was made at Springtown, N. Y., where the old buried bed-rock gorge was found near the Wallkill Valley Railroad Bridge and was shown to be at a depth of 270 ft., extending 79 ft. below sea level. Southward, the elevation of bed-rock in the old stream bed rises rapidly until, at Libertyville, the bed-rock floor was at Elevation 67, or a rise of 147 ft. in 5 miles, an average of about 30 ft. per mile.

Design and Construction of Wallkill Pressure Tunnel.—The design of this tunnel was simplified by the fact that the rock to be penetrated was entirely Hudson River shale of almost uniform character. It was not necessary to consider, as in the case of the Rondout Tunnel, the rates of excavation progress to be expected, and the difficulties to be encountered in various broken and porous formations. The principal consideration in establishing the depth below the bed-rock surface was to provide adequate rock cover along the entire length of the tunnel.

The probable depth to which the rock might be decomposed and the general strength of the rock as it lies in the ground were also regarded as of prime importance. This kind of rock is not deeply affected by weathering, and although the ground-water level was doubtless much lower in pre-glacial times, there is no evidence that the rock was materially weakened except superficially. The ice sheet removed nearly all the loose and decomposed rock of that time, leaving the surface generally fresh and polished. This shale formation may be regarded as generally rigid enough to sustain itself and yet sufficiently yielding to make many open seams or joints improbable at the depth of the pressure tunnel. The great body of gravel and sand filling the main part of the buried gorge is indicative of a large water storage and suggests caution. Even so, a cover of 150 ft. of slate would seem to afford ample protection to the tunnel, because at this deepest point the rock is likely to be exceptionally fresh and sound.

The tunnel was accordingly designed with a pump shaft in the rock, with a minimum depth in earth, just east of the buried gorge, for convenience in discharging the drainage into the Wallkill River when emptying the aqueduct. The tunnel grade beneath the lowest point of the bed-rock of the pre-glacial gorge was covered by 150 ft. of bed-rock. The drainage shaft for the Wallkill Tunnel was placed near the Wallkill River and the spacing of the five other shafts was balanced in accord with this location of the drainage shaft. Although six shafts were sunk for this 4½-mile tunnel, eight of them were found to be necessary for the more complex conditions at the Rondout Tunnel, which was about the same length.

The general uniform quality and attitude of the thin beds of the Hudson River shale, together with the absence of open joints or porous beds carrying

heavy flows of water, made for comparatively rapid progress and low expense in the constuction of the Wallkill Tunnel. The contract price per linear foot in the Wallkill Pressure Tunnel, including shafts, was $146.31, compared with $248.46 per ft. in the Rondout Pressure Tunnel. This difference in price was due mainly to the difference in the geologic structure in the two valleys. Fig. 11 is a view in the Wallkill Pressure Tunnel, showing the prevailing structure of the Hudson River shale and its habit of breakage in the tunnel excavation. Concrete arch forms may be seen in the background.

The only hard rock encountered was for a distance of several hundred feet near the south end of the tunnel. It was very hard quartzitic sandstone, and it required from 20 to 24 hours to drill the heading as against 4 to 5 hours in the shale. The water encountered during the excavation of this tunnel amounted to 500 gal. per min. entering through joints, with no great flows at any one place. It was noticed that the inflow remained about constant for the entire siphon during the working period. This was supposed to be due to the great depth of the tunnel below ground-water level, so that at no point was the water-table depressed to the tunnel level, and also because there was slow circulation and no abnormal conditions.

As the Hudson River shale from the tunnel was not considered a satisfactory aggregate for concrete, the specifications excluded its use, and the contractor opened a quarry in the Shawangunk grit at Bonticou Crag, at the north end of the line, the nearest source of concrete stone. This quarry proved to be an expensive source as it was situated high on the steep slopes, making access difficult; there was no level bottom for loading cars; the steep down-hill dip of the grit strata made it difficult to operate drills; and the hard and abrasive quality of the quartzite caused rapid wear in drills and crushers. The sand for the concrete was secured from the Rosendale sand plain near the Wallkill Valley Railroad track, a haul of 9 miles. Sand deposits near the line of the tunnel were explored, and although the material was generally coarser than the fine water-washed Rosendale deposit, it contained enough fine material to make it necessary to remove the silt by washing.

Hydrostatic Test.—When this tunnel was first filled with water to the hydraulic grade, the outward leakage was about 1 100 gal. per min. This leakage rapidly diminished and, after several years, it became as low as 30 gal. per min. for the 4½ miles of tunnel, the reduction being due probably to the closing of the fine seams in the slate. When the first test was made, the water came to the surface at several places, particularly from drill holes which penetrated to the tunnel level. These holes formed active springs between Shafts 1 and 2, and softened the drift for considerable areas, but they finally ceased to flow.

Cut-and-Cover Aqueduct in the Wallkill Valley

The Tertiary peneplain on the easterly side of the Wallkill Valley is an open gently rolling country, the average elevation of which adapted it for the construction of the aqueduct in open cut for a distance of 22 miles, extending

from the uptake shaft of Wallkill Pressure Tunnel to the northwest margin of Moodna Valley which is also crossed by a deep pressure tunnel. Through this intervening upland, which forms a base-leveled divide, the deposits left by the glaciers presented favorable and easily excavated materials for the aqueduct trench. In these 22 miles, there were only two deep and heavy cuts, although the line is remarkably direct. Such a condition is due to the perfection of the base leveling or planation in Tertiary time, that is, the wearing down of the country to a plane, due to the long continued and unchanging level with reference to the sea.

Throughout the stretch, the prevailing material overlying the Hudson River shale is compact, glacial till, frequently requiring the use of explosives, except for 3 miles at the northerly end, between Ireland Corners and New Hurley, N. Y., where the east side of the valley is covered with kame deposits, evidently laid down while the center of the valley was occupied by a mass of ice. For 3 miles the aqueduct trench was excavated in this washed gravelly drift, as far south as New Hurley, where the line swings to the eastward, leaving the soft deposits and continuing south for many miles in hard glacial till. This difference in quality of materials affected the type of construction, the compact drift proving the more economical in cost of construction. For example, at the north end in the loose, water-deposited ground, an aqueduct with a wide base was required, and the payment lines for excavation were fixed on a slope of 1:1; whereas, in the solid ice-compacted till to the south, the structure was built with a narrower base and the trench was excavated to side slopes of 6:1. The cost per foot of the completed aqueduct in the modified or loose drift was $58.73, whereas in the adjacent compact glacial till, the cost was $48.06 per ft.

The Moodna Tunnel

Before it was decided to cross the Hudson River somewhere within the Highlands, there had been no Moodna problem. A crossing in the open valley region such as that originally proposed farther north at New Hamburg, would have avoided the whole Moodna section. As soon, however, as the crossing of the Hudson became fixed so much farther south, the line of the aqueduct was thereby established, approaching the Highlands on the west side of the river, and the crossing of the Moodna Valley assumed considerable importance. The Moodna is a comparatively small stream entering the Hudson just north of the Highlands, with its lower course lying across the most direct aqueduct line. The nature of this tributary, together with the character of the material through which it flows, suggests considerable drift filling.

By the time this problem came to be considered, it was known that the Hudson itself was very deep, several hundred feet at least. It seemed reasonable, therefore, to expect that a tributary such as this would have cut down to a somewhat similar grade. It was also appreciated from the studies of the Wallkill Valley, that the pre-glacial Moodna had probably been a larger stream draining some of the present upper Wallkill territory. In that case, the ancient Moodna must have been a more important stream than

the present one and probably had a somewhat different course. All this argued for a valley or gorge of much greater prominence than the present surface channel, but what its forms and profile was, no one could tell. The alternative Hudson River crossings in the Highlands involved corresponding changes in the location of the Moodna Tunnel, the lines farther south allowing the Moodna crossing to be located farther up stream. The Storm King Crossing, however, which was finally adopted, gave preference to a line across the Moodna at its farthest down-stream position and permitted comparatively little chance for shifting.

It was planned at first to reach the Highlands margin with a pressure tunnel and to connect with the Hudson River Tunnel by a cut-and-cover aqueduct at grade along the northerly face of Storm King Ridge. It was finally decided, however, to construct the Moodna Pressure Tunnel on a more direct line and to continue at a suitable depth the entire distance to the Hudson River. This plan made it desirable to locate the tunnel as far to the north, down stream, on the Moodna, as natural conditions would permit, and explorations were conducted to determine the facts in detail. The early borings were rather widely spaced, but they soon disclosed that the deeper valley floor was abnormally flat for a distance of at least ½ mile and was covered with 300 ft. of very bouldery drift. Such a profile raised much speculation, the opinion prevailing that considerably greater irregularity probably existed than the borings had yet revealed.

It was known at this time that the gorge of the Hudson was from 500 to 600 ft. deep, and, as the floor of the Moodna Gorge, only two miles distant, was shown by the borings to be only 50 ft. lower than the present water level of the Hudson, the argument was felt to be strong in favor of a deeper inner notch somewhere in the Moodna Valley floor. The borings showed that there could be no notch wider than 200 ft. in the floor, and it was decided that a very deep canyon need not be considered. It is surprising to find so flat a valley bottom at this elevation, in view of the fact that the Hudson Gorge is at least 700 ft. deeper only a short distance away. The stream ought to have cut a deeper notch within this bottom. It is probable that at least two causes unite to develop this abnormally flat form. Glacial scouring doubtless aided, and, probably, also the ancient course lay more nearly parallel to the line of borings than that of the present Moodna. On the whole, however, the Moodna profile appears to be the most abnormal of any on the aqueduct line.

It was necessary to determine the character of the rock of the valley floor, in addition to the depth of the gorge, but this of itself did not require a very extensive series of borings. It was easily found that the chief formation was the Hudson River shales and sandstones and that although beneath them and above the basal gneisses, there must be 1 000 ft. of limestones and 500 to 600 ft. of quartzite, only very short stretches of tunnel would penetrate either formation. No quartzite was encountered in the tunnel excavation and only about 200 ft. of limestone. At places where these formations would normally be expected, they have been cut out on the

tunnel line by faulting. Only one stretch of ground exhibited a change in formations or any unusual structural relation. It was discovered in one of the earlier borings that crystalline rock like that of the Highlands occurred in the floor of the Moodna, under the deep cover of drift, but the adjacent borings showed only Hudson River sandstones and slates. Normally, the quartzite and limestone should lie between, but no such occurrences were discovered.

When the tunnel was driven, it was found that the stretch of crystalline rock was less than 200 ft. wide, that it was bounded on both sides by fault crush zones in which the rock was so weak that it required timbering, and that the formation immediately in contact on both sides is Hudson River shale. Undoubtedly, this crystalline strip is a remnant left stranded after two periods of faulting, and it is reasonably certain that it does not extend up from the granite basement, but instead is completely cut off below by these two faults. Doubtless, it would be possible, at somewhat greater depth, to pass beneath such a block as this and not encounter the granite.

The Great Thrust Fault.—At the margin of the Highlands where the tunnel line passes from the Hudson River slates and associated rocks to the Highlands granites and gneisses, the transition is sharp. A short distance north of the line, limestone may be seen along the contact within a few feet of the granite. A short distance south of the line, the limestone does not appear, but slate lies near the granite contact. North of the line, ½ mile or more, slate and granite can be seen in contact with a crush zone strongly developed and with the crystalline rock lying above the slate, the contact plane dipping at an angle of approximately 45° toward the Highlands beneath the granite. This represents an overthrust fault, the granite having been pushed up over the slate on a 45° plane.

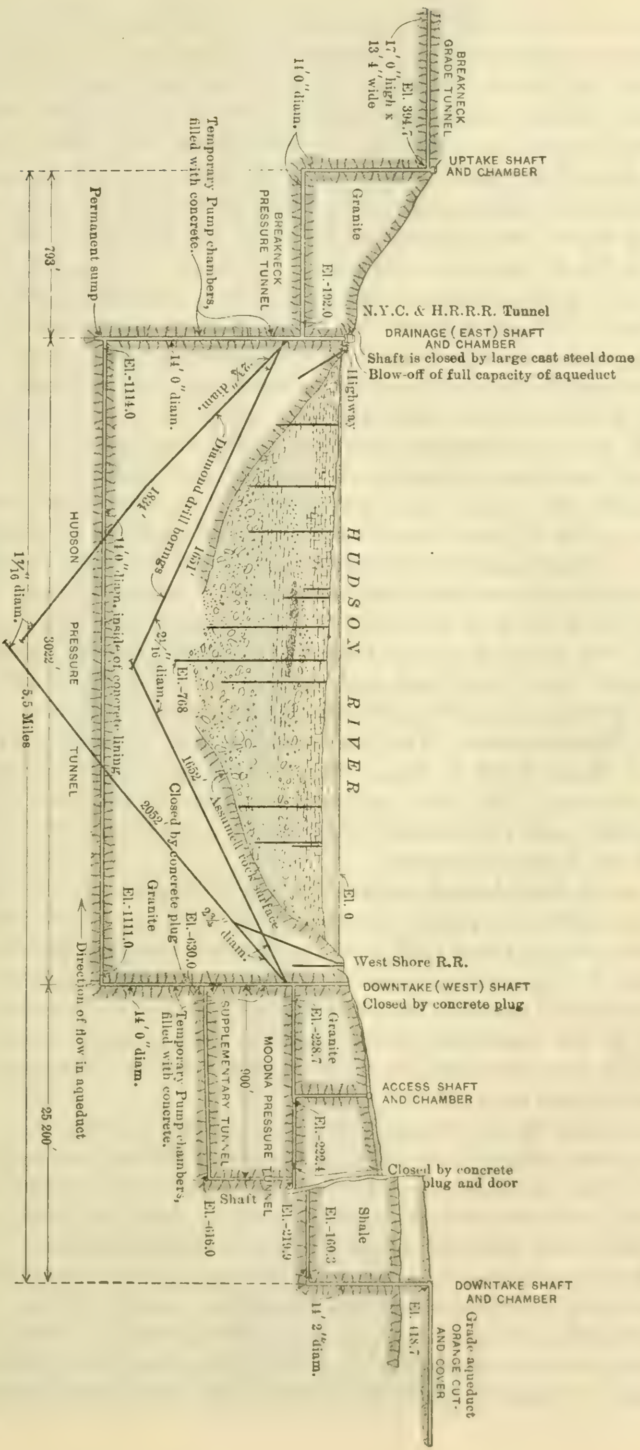
Borings placed so as to develop this structural condition at depth indicated the same fault on the tunnel line and with about the same angle of dip. When the tunnel was constructed, the fault was encountered as indicated. At that depth, however, about 200 ft. of limestone intensely crushed and rehealed, and so deformed by that process that its bedding could nowhere be determined, was encountered. On the west side of the limestone, the Hudson River formation continued and beyond the fault to the east only granite was found. The rock was badly crushed and slickensided and sheared in the vicinity of the granite, and a similar crush zone was developed at the contact between the Hudson River slates and the limestone 200 ft. farther west. Except at the two more pronounced crush zones referred to, the ground in the tunnel was good and sound for construction purposes and required no special or unusual attention. The great fault at this point which probably represents a displacement of 2 000 to 3 000 ft. and perhaps more, is crossed by the aqueduct without any structural difficulty. The cost of construction per linear foot of this tunnel was the lowest of any pressure tunnel on the aqueduct. It is evident from the success of the pressure tests and later operation that the depth of the tunnel is adequate and that no danger exists, due to structural weakness of the rock or to erosion notches, of sufficient consequence to interfere with the success of operation and permanence.

The Hudson River Crossing

A great number of factors were involved in fixing the location for crossing the Hudson River, some of which involve advantages of aqueduct location through the intervening country between the Catskills and the Highlands and others which apply in equal measure to its southerly extension toward the city. The vital and decisive factor, however, in selecting the exact location concerned the geological conditions at the crossing itself.

The possible places for crossing may be divided into two groups. One known as the "New Hamburg group" included all the crossings considered in the territory north of the Highlands where somewhat metamorphosed and badly deformed sedimentary rocks of the Cambro-Ordovician Age, including shales, slates, limestones, and quartzites, constitute the formations through which the tunnel would have to pass. The other known as the "Highlands group" represented the possible crossings within the limits of the Highlands. This Highlands region is characterized by crystalline rocks, including chiefly granites and gneisses of considerable variety, more or less disturbed by deformation, but, in general, comparatively sound. The New Hamburg group was explored sufficiently to determine that there would be a long pressure tunnel where limestone would be encountered under conditions encouraging to structural weakness. This ground north of the Highlands is known to be badly disturbed by faulting, and these conditions could not be avoided. It is a good general principle to avoid such objectionable weaknesses if it can be done, by locating in ground of more favorable quality. On this account, in large part, the Highlands group of crossings came into additional prominence. They avoid the weakened and deformed sedimentary series, except in so far as they would be encountered in crossing the Moodna Valley.

The different possible lines within the Highlands were further studied for individual differences. When the locations were studied in detail, it was found that the most southerly lines, especially the West Point line and any possible line farther south, would cross a large fault and crush zone under the Hudson River. It was also certain that all the southerly lines would cross much more varied rock types, and it was considered desirable to avoid this complication. Accordingly, the Storm King line at the extreme northerly margin of the Highlands was finally adopted as the best location. It was the opinion of the geologists that the whole section could be constructed at this point through granite of a single type from one side of the river to the other without crossing any major structural weakness; whereas, an equally favorable combination of conditions could not be found elsewhere. It was recognized at the outset that the depth of the river gorge was not known and perhaps would be difficult to determine. This was also true of all other points. It was recognized that this particular location, by reason of glacial action, might be unusually deep. This seems to be fairly certain since the final explorations were made, but the argument in favor of the Storm King crossing was not offset by any of these considerations, because of the great advantage of locating this critical section of the aqueduct at a place where the major uncertainties of rock quality and structural weakness were reduced to a minimum.



CROSS-SECTION OF HUDSON RIVER CROSSING, LOOKING SOUTH, TOWARD WEST POINT.

FIG. 12.

0 200 400 600 800

SCALE IN FEET

Preliminary explorations were made on all the lines before the final choice of the Storm King location. Subsequently, extensive explorations were conducted on the Storm King line. Borings were put down in the river under extremely difficult conditions and to extraordinary depth. Fig. 12 is a geologic cross-section under the Hudson River, and shows the deep preglacial drift-filled gorge in the granite, the deep shaft and pressure tunnel of the Catskill Aqueduct, and the inclined diamond drill holes for exploring the rock before the question of the depth of the tunnel was decided. A depth of 768 ft. below the surface of the water was reached in the middle of the river by the deepest boring, which even at that depth did not reach the rock floor. At each side of the center, borings penetrated 500 ft. before reaching rock. At this stage it was believed that the results obtained had demonstrated the feasibility of the crossing, but sufficient data had not been secured to determine the depth and detail of design so that construction could proceed. It was determined, therefore, to sink test shafts on both sides of the river and from them to explore the underground conditions by inclined drill holes under the river. The first pair of holes, one from each side, was projected so as to reach beneath the center of the river at a depth of about 1 400 ft. Sound granite was obtained from the cores for the entire depth. After these holes were completed, a second pair was projected to cross beneath the river at a depth of about 950 ft. These holes likewise penetrated sound granite. On the basis of this information, the tunnel was placed at a depth of 1 100 ft. below river level, and was constructed without special difficulty.

The Hudson River Pressure Tunnel is located at the north edge of the granitic Highland area. The large building, Fig. 13, near river level marks the East Shaft, 1 100 ft. deep. The buried gorge is nearly 800 ft. deep to rock. The top of the hills marks the Cretaceous peneplain or base level, whereas the inner rock terrace, which may be noted about 100 ft. above water level, is the Tertiary peneplain.

It was at first planned to have the aqueduct approach the Hudson River section at hydraulic grade connecting with the tunnel under the river by a down-take shaft. Later studies of the Moodna crossing, however, led to the adoption of a continuous pressure tunnel connecting the Moodna, Hudson, and Breakneck Tunnels. Thus, the tunnels constituted one system at different levels. At the connecting angles between these pressure tunnels, structural weaknesses later developed in the solid rock when full pressure was applied, and repairs were required.

No faulting of any consequence was discovered in excavating the tunnel. Two or three slips were noted near the east end, but the original judgment that the river could be crossed at this point without penetrating any great structural weakness such as a crush zone or fault line was substantiated. In certain zones, however, the rock is under unrelieved strain, still preserved from the deformations of earlier geologic time. In the deeper workings, this strained rock at certain places had a tendency to scale off with violent explosions. Sometimes this scaling happened suddenly, breaking from the wall where previously the rock appeared to be sound. This scaling, which was known to the workmen as "popping rock", was encountered at several places and also in

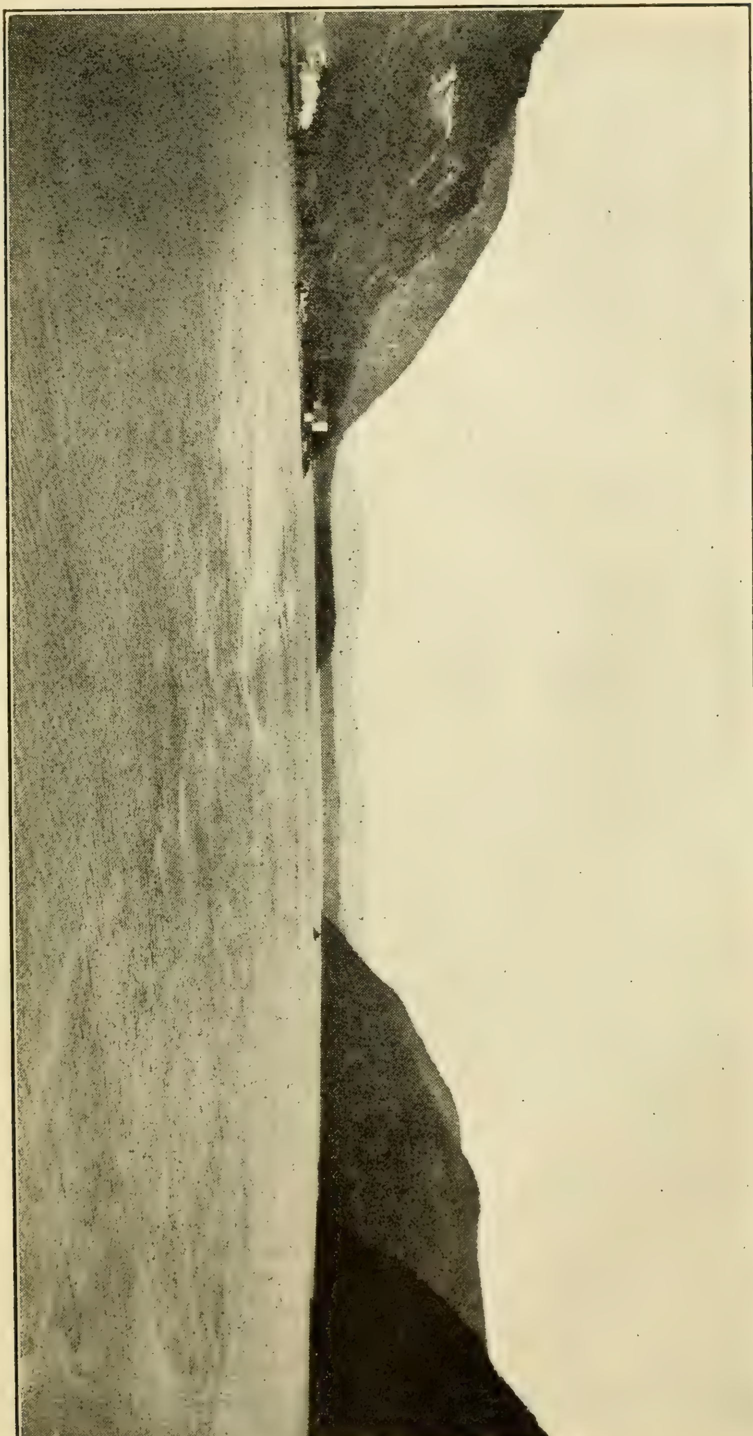


FIG. 13.—LOCATION OF HUDSON RIVER PRESSURE TUNNEL.

other tunnels of the aqueduct, but nowhere did it give as much concern as at the Hudson crossing. This condition of the rock is believed to have developed the weakness in the Hudson River end of the Moodna Tunnel after full pressure was established, making repairs necessary.

At one stage of the construction an unusually heavy flow of water from the joints penetrated by the tunnel near the east shaft required a large emergency pumping plant; the small equipment that had served successfully in sinking the east shaft was inadequate for the sudden flow of water just after turning the heading under the river. Fear of water had been expressed in the consideration of the tunnel project beneath the Hudson, and this sudden appearance of a heavy flow was thought to be ominous. However, after the joint had been closed by grouting, no further trouble was experienced. There was no indication of a direct connection with the Hudson River water itself and the large pumping equipment was not needed, the tunnel, as a whole, being fairly dry. The quantity of water for the 3 000 ft. of tunnel did not exceed 110 gal. per min. at any time after passing the inrush of the ground-waters stored in the joint system.

Moodna Repair.—When the Moodna-Hudson-Breakneck Siphon was subjected to hydrostatic tests, leakage developed. Subsequent examination showed that the lining of the Moodna Tunnel had ruptured at its junction with the down-take shaft of the Hudson River Tunnel and that water escaped to the surface through joints in the rock. There were, also, some cracks in the lining in Breakneck Tunnel at the river shaft.

Special study was given to the probable cause of this unexpected weakness where the rock had originally appeared to be sound and without water. The conclusion was reached that the rupture developed where the tunnel crossed one of the zones in which the rock is under strain. If penetrated at a little greater depth, it would have produced "popping rock", such as has been encountered in the deeper portions of the tunnel beneath the Hudson. Perhaps it was not unstable enough at the shallow depth to break without some additional help. This additional impetus appears to have been given by the bursting pressure supplied by the water-filled tunnel, when the rock was subjected to the operating pressure. This unstable ground then yielded and the tunnel lining was ruptured, thus allowing the escape of water into the joints connecting with the surface. On the Moodna side, therefore, where this disturbed zone was apparently several hundred feet in width, it was decided to make repairs by abandoning about 900 ft. of the Moodna Tunnel adjacent to the Hudson Tunnel and constructing a connecting step 400 ft. deeper. Rupturing under similar conditions was elsewhere corrected by caulking the cracks and by grouting.

Nature of the Hudson Gorge.—Because of its great depth, the Hudson Gorge has been a favorite topic for geologists and engineers. It is well known that the Hudson is a very ancient river and that at one time the Continent stood higher than it does at present. Under such conditions, the river cut its gorge, which can be followed by soundings nearly 100 miles out to sea where it is a veritable canyon from 3 000 to 4 000 ft. deep.

Knowledge of these conditions, together with the fact that hitherto no explorations had determined the exact depth of the gorge anywhere along its course below Albany, N. Y., gave especial uncertainty to the problem when the work first began. Later explorations have tended to show that although the Hudson River is very deep, more than 300 ft. at New York City, yet there are certain abnormal features of the gorge at the Storm King crossing that invite comment and require some additional explanation. The Hudson Gorge at Storm King is too deep and too wide to be wholly consistent with the cross-sections at other points. In its deepest part, below 300 ft., it is wider than at New York City, and it is known to greater depth. It is this fact, however, of greater width below the 300-ft. level, even though the rock is more substantial, that leads to the conclusion that the gorge has been "over-deepened" and enlarged by the glacial ice at the entrance to the Highlands. This is one of the clearest cases in the region of glacial over-deepening and enlargement. Probably nowhere else along its course is the Hudson so deep. The ice seems to have crowded into this notch between Storm King and Breakneck Mountains, gouging out the rock considerably deeper than it had been cut by the river itself. It appears, therefore, that the Storm King crossing may have required a somewhat deeper tunnel than would have been necessary at some other location, but it had other advantages quite offsetting this factor, and it was on these that the choice was based.

Special Features in the Highlands

The aqueduct through the Highlands comprises a succession of grade tunnels, cut-and-cover aqueduct, and steel pipe siphons. A variety of geological conditions was encountered, which were chiefly of scientific interest, but which had some bearing on the original questions of location and design.

At one place in Foundry Brook Valley, a crush zone was encountered, which, at first, caused some concern, because the drill recovered only what appeared to be sand, but which proved later to be crushed and decayed material. This zone also carried much water, and one of the borings that penetrated it furnished an Artesian flow, which later was made the basis of a special claim for enhancement in the value of the land taken by the city. Another section of unusual character and local importance was in Garrison Tunnel, where a long stretch of residual decayed rock was encountered at the north end. It was assumed in the original survey that the rock which was a variety of gneiss, would be comparatively sound. In excavating the tunnel, however, a patch of pre-glacial residuary decay material was found at the north end beneath the drift, which the glacier had failed to remove. This gave trouble when excavated. A fault zone in the middle of the tunnel showed similar disintegrated material, but did not cause much trouble.

Sprout Brook Valley was thoroughly explored, but on account of the depth required for a tunnel, a steel pipe siphon was adopted as more economical, although a tunnel is feasible as far as geological conditions are concerned.

Fig. 14 is a view of the steel pipe siphon across Sprout Brook Valley. The valley is eroded on a narrow band of crystalline limestone with granite hills

on each side. The bottom of the valley is filled to a depth of 100 ft. with glacial drift. The opposite hill is penetrated by the aqueduct tunnel (Cat Hill Tunnel) for ½ mile.

In Peekskill Valley, the formations previously encountered on the north side of the Highlands were found to be closely folded, and affected by weathering and decay to a considerable depth. After exploration sufficient to map the occurrence, attitude, and condition of these formations, the steel pipe siphon was adopted as the method both for avoiding a deep pressure tunnel and some of the uncertainties of behavior of these rocks. Similar problems were encountered at numerous places where either small grade tunnels or short pressure tunnels were constructed.

Kensico Dam

At Valhalla, N. Y., a short distance north of White Plains, within about 20 miles of the city, it was decided to locate a storage reservoir. This is the site of the old Kensico Reservoir that was already a part of the New York City System, storing the waters of the Bronx River. However, in order to serve its purpose in the Catskill Project with a storage adequate for a three months' supply, it had to be greatly enlarged, and the geologic problems of this work were those incident to the greater importance of the high dam necessary for the increased storage.

At Kensico, the valley is comparatively narrow and deep, and its sides are rocky, although the bottom is filled with drift. It was known from the outcrops in the vicinity that the rock formation of the west side of the valley, at this point is Manhattan schist, that the east side is granite gneiss of considerable variety belonging to the so-called Fordham gneiss series, and that the Inwood limestone formation must lie in the bottom of the valley. It was evident, therefore, that the dam would stretch across the three important formations of the region, a fact which, in itself, would present no particular disadvantages unless unusual weaknesses, especially those relating to fault movements, should be found. Fig. 15 is a view of the foundation of the Kensico Dam. It is a narrow V-shaped gorge, at contact of Fordham gneiss (left) and Inwood limestone (right). The excavation is more than 100 ft. below the ground surface.

Explorations showed that the limestone, which was exposed in the bottom of the valley (Fig. 15), is 400 ft. thick and that, as a whole, it was in no poorer condition than the other formations. Perhaps, it is in better condition than the schist, because the latter is so much more broken.

The chief problems to be settled by detailed exploratory work were:

First.—The amount of drift cover and its character, especially its water-bearing quality as affecting construction.

Second.—The extent and distribution of weak zones or any broken condition of the rock.

Third.—The extent of weathering disintegration and decay.

Fourth.—The perviousness of the rock itself.

All these questions were determined within reasonable limits and were consistent with the earlier general estimate of conditions. After all the exploratory borings had been made and the facts bearing on these points had been summarized, it became evident that the more northerly lines had the soundest rock. The dam was placed, therefore, some distance north of the site of the existing old dam. On account of the discovery of considerable rock decay, especially at the junction between the gneiss and the limestone, and the presence of considerable jointing in the rock itself, particularly in the Manhattan schist, a design was adopted that provided for stripping and considerable excavation of the surface rock and a deep cut-off trench.

Of almost equal importance to the question of location and the quality of foundation is the problem of materials for construction. The dam required approximately 1 000 000 cu. yd. of structural material and the decision to use stone facing, if a suitable quality could be found near enough to utilize economically, emphasized the problem of local supply. The basal gneiss series on the east side of the reservoir carries a large quantity of igneous intrusive rock of essentially granitic composition. This rock, the Yonkers gneiss, is of strikingly granular habit in most exposures and disintegrates to a sand under certain kinds of exposure. However, blocks of this stone used in the oldest buildings of the region are well preserved, and the stone shows high strength and a satisfactory resistance to the ordinary disintegration tests. Even the somewhat weathered material, considered by no means in its best condition, shows surprisingly good results under the tests. The color of the stone and its structural markings are considered to be very attractive. No other masonry structure on the Catskill work has been more successful from the standpoint of the material used.

The East View Concrete Disintegration.—From Kensico Reservoir, the aqueduct turns toward the city with cut-and-cover and short pressure and tunnel sections with comparatively little incident beyond the occasional uncertainties regarding the quality of the rock or the encountering of exceptional decay and disintegration. In Elmsford Tunnel north, a long stretch of excessive decay introduced the usual difficulties in construction. The only unusual feature, however, sufficiently different from those encountered in many other places, to warrant special attention, was in the East View Tunnel, about midway between East View and Kensico Reservoir. After this tunnel was completed and had stood for some time, it was discovered that, along a considerable stretch of roof and side-wall, the concrete lining was badly disintegrated. Patches were discovered that had completely softened and, in a few places, parts fell from the roof. It was found, however, that the trouble was not general, suggesting that there was some particular cause connected with the ground itself, rather than any fault of construction.

The aggregate used in the concrete in this tunnel included a great deal of limestone. At the time of construction, the suitability of limestone aggregate was not questioned, because this tunnel was put under comparatively little pressure and there was no thought of particular difficulty from the surrounding conditions. On investigation of the condition of the concrete, it was found that many of these limestone fragments had been completely de-

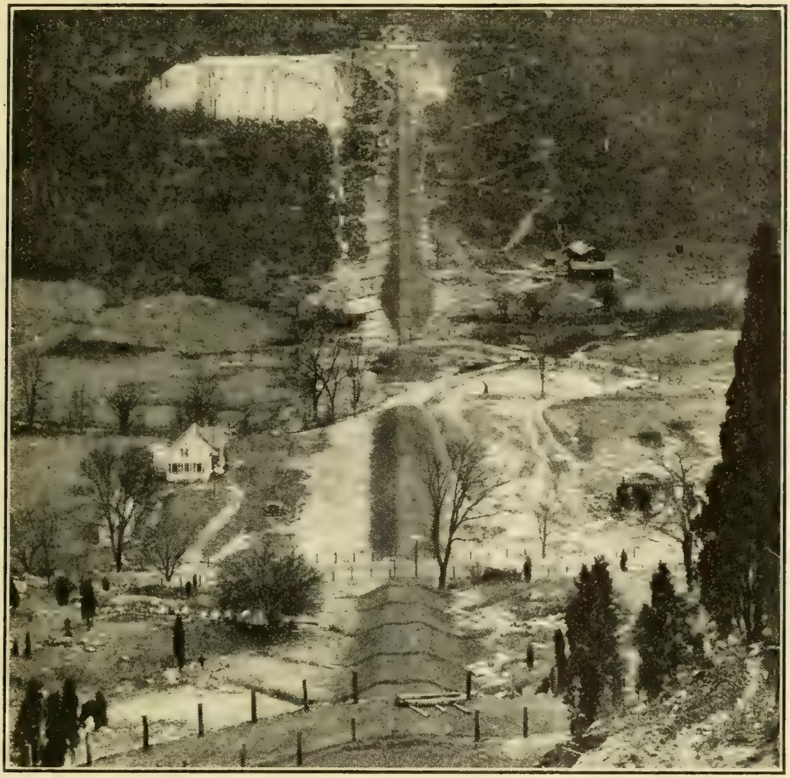


FIG. 14.—VIEW OF STEEL PIPE SIPHON ACROSS SPROUT BROOK VALLEY.

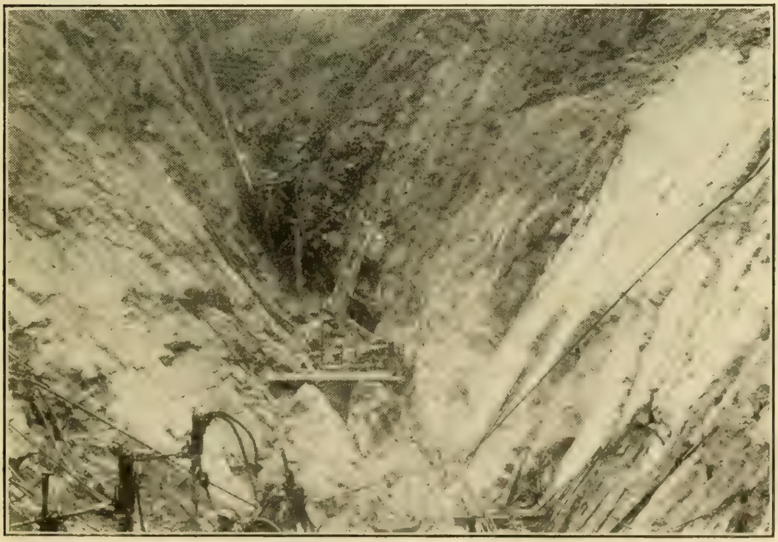


FIG. 15.—VIEW OF FOUNDATION OF KENSICO DAM.

stroyed. The experiments in this tunnel further emphasized the unsuitability of limestone for concrete aggregate under miscellaneous or uncertain conditions, especially if there is any probability of acid waters coming in contact with the concrete.

An investigation showed that the waters trickling into the tunnel in the part affected were charged with sulphates and had a destructive chemical action. Examination of rock that had been thrown out from the tunnel and from the borings made in this part of the ground showed large quantities of iron sulphide as a constituent. Blocks that had been exposed at the surface since construction were badly oxidized and showed abundant development of sulphate of iron which had been accompanied by the production of free sulphuric acid. A spoil bank of this kind of material had been thrown out on the surface almost directly over the most seriously affected part of the tunnel. From these facts it was concluded that the real cause of the trouble lay in the oxidization of the sulphide content of the rock, and the opening of an underground escape for the downward circulating water which therefore could leach these soluble matters out of the rock dump and reach the tunnel immediately below with the result of continuous destructive attack on the tunnel lining. Study of the methods of overcoming the trouble emphasized the difficulty of removing the cause. It was finally decided to reinforce the weakened part by lining it with different material. Accordingly, a brick lining was put in and all voids were filled with cement grout for a distance of about 2 000 ft.

The City Tunnel

The aqueduct reaches Hill View just outside the northern boundary of New York City at Elevation 295. At this point, an equalizing reservoir with a capacity of 900 000 000 gal. is located, which distributes directly to the city. After exhaustive study of alternative methods a deep pressure tunnel was adopted to extend from Hill View southward through the city to Brooklyn, N. Y. This was to become the trunk line from which water could be taken at many points. As finally worked out, the water was also carried to Staten Island and the Borough of Queens by means of steel pipe extensions. The adoption of a tunnel plan emphasized the matter of natural ground conditions and made it imperative to conduct extensive investigations. The manner in which these were co-ordinated with the other engineering studies forms an instructive illustration of the manner in which the Catskill Aqueduct project was handled.

A thorough preliminary engineering and geological study was made before any steps toward exploration were taken. Taking into account chiefly the engineering works already in place in New York City and the known difficulties due to city development, three trial lines were laid out by the engineers between the starting point and objective in Brooklyn. At this stage, the geologists were asked to make a study of the surface conditions along these three lines and the adjacent ground to a considerable distance on each side. It was then necessary to decide whether a shift of any one of the lines would materially improve these conditions. After careful study it was found that a

reasonably clear choice of a line could be made, but that certain unfavorable features could be avoided by shifting it somewhat from its original course. The choice was based on ground conditions, without sufficient knowledge of other factors to be certain that this new course would be practicable from an engineering standpoint. Therefore, it went for the second time to the Engineering Staff for consideration, with the result that minor modifications were suggested for re-study. These modifications were found to be generally consistent with the geological conditions, and, thus, with very little additional modification, the course that the aqueduct should take through the city was tentatively established.

These preliminary studies were sufficiently detailed to determine the points of uncertainty that would require active exploration, the nature of these uncertainties of condition, the purpose of these additional investigations, and something of the amount of exploratory work required. All the exploratory work was done by borings, but no conditions were discovered, after the course was fixed that required material shift of the line.

General Questions.—In conducting these studies, the following general questions were kept actively in the foreground:

1.—What is the character of the rock along the projected conduit at the proposed depth?

2.—Is the depth proposed an appropriate one for a pressure tunnel of this character?

3.—Does the character of the rock vary sufficiently to affect the cost or the safety of the tunnel, and would anything be gained in either respect by a change of position or change of depth?

4.—What principles are most fundamental in weighing the evidence and in judging these points?

5.—What are the most questionable points along the proposed tunnel and where is exploratory work necessary to determine the local conditions fully enough to satisfy the needs of this project?

6.—What borings or other field investigations should be made to determine the facts about the uncertainties along the line and to make certain of the practicability of the pressure tunnel?

Geological Formations of New York City.—The variety of rock types within the city limits is somewhat greater than along the remainder of the aqueduct, but a knowledge of the three standard formations is sufficient to an understanding of the nature of all the local problems. Originally, these three formations lay one above the other to a very great thickness, but they are now folded together so closely that the parts exposed after long erosion stand almost on edge. On this account the formations appear at the surface as long strips with a general northeast trend. The bottom and the top formations are more resistant to erosion and weathering than the one between them. As a result, the major topography of Manhattan and all the regions lying to the north of the East River and Long Island Sound have developed a parallel ridge topography consistent with this structure. Narrow valleys or the depressions lying parallel to this structural trend are underlain in most cases by the

softer rock (limestone) and the ridges are either one or the other of the two resistant members. These formations are: (1) the Manhattan schist at the top of the series; (2) Inwood limestone, the intermediate member; and (3) the Fordham gneiss, the basal member.

Originally, these formations were sediments varying from sandstones and limestones to simple mud shales. Now, after long metamorphism, these are gneisses, marbles, dolomites, and schists, each type presenting many variations in minor character and quality. The Manhattan schist, the youngest member, is essentially a mica schist. It is usually comparatively coarse and flaky in structure and inclined to be crumpled and somewhat bunchy. It is impregnated with igneous material which gives the rock a bunchy appearance or introduces stringers or dikes of pegmatite. Rock of this formation, because it is made up of very durable minerals and has a structural habit that makes it work in a massive form with reasonable satisfaction, has been considered suitable for tunneling.

The Inwood limestone is a coarsely crystalline dolomitic limestone. At depth, the rock is sound, but at the surface it crumbles readily under weathering influence and is comparatively easily eroded. Therefore, these belts of limestone are the lines of depression in the local topography. On the general principle that limestones of all grades are less stable where solution is possible than rocks made up of crystalline silicates, it was considered that long stretches of the Inwood limestone should be avoided if possible.

The Fordham gneiss is a black and white banded rock, made up chiefly of schistose and granitic bands. In some places much granite occurs in this formation, such as the "Yonkers gneiss". On the Brooklyn side, another similar occurrence is known as the "Ravenswood granodiorite". It is composed of durable material, but on account of its strongly banded structural habit, it tends to break into slabs, thus introducing a behavior somewhat more troublesome than that of the Manhattan schist.

Principles of Judgment.—At least one other structural feature must be considered. This is the crush zone or fault zone along which movement has taken place and along which rock is broken or weakened enough to encourage deeper decay and alteration than at other places. On the surface, these weakness lines are indicated by depressions. Relying on such knowledge of the importance of these conditions as was appreciated at the inception of this enterprise, the following principles were accepted as suitable guides, both in the matter of choice of location and exploration:

First.—It is in general desirable to avoid location in or near to a contact between two formations, as this is likely to be a zone of weakness underground.

Second.—Nearly all fault lines and crush zones are also lines of special weakness, and on this account it is desirable to avoid them in the manner indicated in Principle 1.

Third.—The behavior of the Inwood limestone is more uncertain than any of the other formations and, therefore, should be avoided as much as possible.

Fourth.—The simple igneous units such as the Yonkers gneissoid granite and the Ravenswood granodiorite are probably more uniform and consistent in their behavior under tunneling than any other formations, because of their simple crystalline character. For somewhat similar reasons the Fordham gneiss and the Manhattan schist may be considered comparatively satisfactory formations, although neither of them is as uniform in structure as the other two.

Fifth.—Along the lines of contact between the several rock formations and along crush zones, superficial decay and disintegration is much deeper than at other places. These places are practically the only points at which construction difficulties are likely to be encountered. They are also the chief points where the inflow of water and falling rock may be expected to be greater than usual.

Sixth.—The deepest erosion, marking pre-glacial stream channels, is to be expected also along the lines of contact and along the crush zones. The depths that these stream channels may reach cannot be determined without exploration. The positions of the most important spots, however, are indicated with reasonable accuracy so that exploratory work can be confined to definite places.

Seventh.—The overlying glacial drift is variable, but, for the most part, is very porous and water-bearing, especially where heavy cover is to be expected. This condition is a factor of importance in considering methods of construction.

Tunnel Location.—Basing judgment of the advantages and disadvantages of the trial lines on the principles just stated, it seemed reasonably clear that one of the three original alternative lines had decided advantages over the others in the proportion of better grade of rock and avoidance of questionable zones. One of the lines had an unnecessarily long stretch in the limestone formation. A second had a considerable length across a part of New York City where the underground formations are wholly obscured by drift. On the whole, the advantage seemed to lie with the trial line that was located farthest to the west, running from Hill View southward past Jerome Park Reservoir, crossing the Harlem River and running almost the entire length of Manhattan Island before crossing to Brooklyn.

In this connection, all the exploratory data available in the city were re-studied and a new geologic map was made of that part of the city within reach of the project. This map showed considerable differences from the standard geologic map of Folio 83 of the U. S. Geological Survey, some of the points being regarded as very radical changes. As a guide to location studies the contact lines between the several rock formations were re-drawn as accurately as possible, and special attention was given to lines of structural weakness and to depressions in the rock floor marking pre-glacial drainage. The course of the City Tunnel was based on these studies. Although this general location was made before additional exploratory work was undertaken, no new conditions were discovered of sufficient importance to require material modification. The question of depth, however, was not settled until the exploratory data from the borings were available.

Questionable Points.—By detailed studies of the ground along the course adopted for the City Tunnel, it became certain that, for the greater part of the distance of nearly 18 miles, the geological conditions were so fully determined and so satisfactory that no exploratory work would be necessary. Ordinary geological interpretation also reasonably established that long stretches of ground, even where direct observations of the bed-rock were not frequent, would not present conditions of sufficient uncertainty to warrant extensive investigation. At four points, however, it was realized that not only were the actual conditions unknown, but the evidence indicated greater probability of weakness than at other places. It was also expected that in places the rock floor would be deeply eroded and show structural weaknesses. These spots would probably control the depth of the tunnel and determine the difficulties of construction. It was advised, therefore, that these points should be thoroughly explored. These four places were:

1.—The vicinity of the Mosholu Parkway;

2.—The Harlem River crossing;

3.—The 125th Street cross-town depression and its extension southward to Central Park; and

4.—The lower East Side from the Bowery across the East River to Brooklyn.

Certain surface conditions suggested the probability of a cross-zone of weakness at Mosholu Parkway. This was not expected to be of as much importance as the others, because of the very substantial Yonkers gneiss type of rock. Explorations, however, showed satisfactory conditions at this point at the depth adopted.

At the Harlem River, the tunnel would cross from Fordham gneiss through the Inwood limestone to the Manhattan schist. This was known to be a line of depression and weakness, and, although the geologic structure in general was well established, the exact conditions had to be determined on the basis of which the depth of the tunnel could be fixed. Explorations were conducted, therefore, in sufficient detail to determine the exact boundaries of the formations and their condition, particularly at the contacts.

The 125th Street cross-town depression is a prominent feature, and it was appreciated in the beginning that it indicated a structural weakness such as a crush or fault-line zone. Explorations at this point extended from 125th Street southward and showed the correctness of this interpretation. The earliest borings indicated not only that crush zone conditions existed, but that the rock floor was eroded to Elevation — 190. The 125th Street depression is one of the deepest erosion lines within the limits of the city, and is much more pronounced than the course of the East River. Exploratory work, carried southward in the vicinity of Morningside Park, as far as 110th Street, indicated a somewhat less prominent weakness extending parallel to the contact of the formations with comparatively deep erosion also along that line. It was partly to avoid the worst conditions of this zone that the tunnel was turned eastward at 106th Street instead of 110th Street. Explorations enabled an accurate map of the boundaries of the formations to be made and

the major structural features were determined. It was these findings that determined the course of the aqueduct and its depth.

The lower East Side of the East River Section also required extensive study, partly because of the greater extent of unknown or questionable ground, the entire lack of outcrops, and the dearth of earlier exploratory data. Nearly all the distance between the Bowery and the Brooklyn side of the East River required detailed exploration. It had always been assumed that the East River follows a zone of considerable weakness or a change of formations. The revised map threw considerable doubt on this assumption and the explorations proved also that the bed-rock condition of the East River south of 30th Street to Brooklyn Bridge is comparatively simple and sound. A little farther to the west, however, between Forsythe and Clinton Streets, lies a belt of ground in which great complexity of structure and very deep decay were discovered.

This decay and disintegration were found to extend extraordinarily deep. The rock floor reaches Elevation — 200 and is below Elevation — 100 for nearly the whole distance. In this section of the rock floor, the deepest part is more than 100 ft. deeper than at the East River itself. Doubtless, the pre-glacial drainage was through this territory across the lower East Side instead of along the present course of the East River. The present course is evidently controlled by the accumulations of obstructing glacial drift which filled the old channel more deeply than some of the adjacent ground, so that when post-glacial drainage was finally established, the new watercourses differed from the original ones.

Additional exploratory work was done at certain other points along the projected line as a check on interpretations and as a basis for contract specifications. Three of the four sections originally chosen for detailed investigation proved to be the critical and controlling ones in determining the nature of the most questionable conditions to be encountered and in deciding on the depth of the tunnel. No others were discovered, even during construction, of so great significance.

Depth of Tunnel.—The comparatively sound conditions of the whole northerly portion of the line to the Harlem River made it possible to construct the tunnel at a moderate depth, about Elevation — 150, to that point. The controlling feature of the next section, however, was the Harlem River, and as it showed a weakened condition of the rock to Elevation 160, it was decided to place the tunnel through this portion at a depth of about 350 ft. below tide level. Fig. 16 is a geological profile of the Harlem River Tunnel of the Catskill Aqueduct, showing the rock penetrated.

At the 125th Street depression, pre-glacial erosion extends to a depth of 200 ft. and the rock is somewhat broken. It became necessary, therefore, to place the tunnel still deeper. It was finally located at about Elevation — 350. As the quality of rock improved, and the floor was much shallower for many miles south, the design adopted allowed the tunnel to rise on an incline to Elevation — 250, and this level was maintained as far south as the vicinity of the complex conditions of the lower East Side, and the East River. The ground of the lower East Side, which showed pre-glacial erosion deeper than

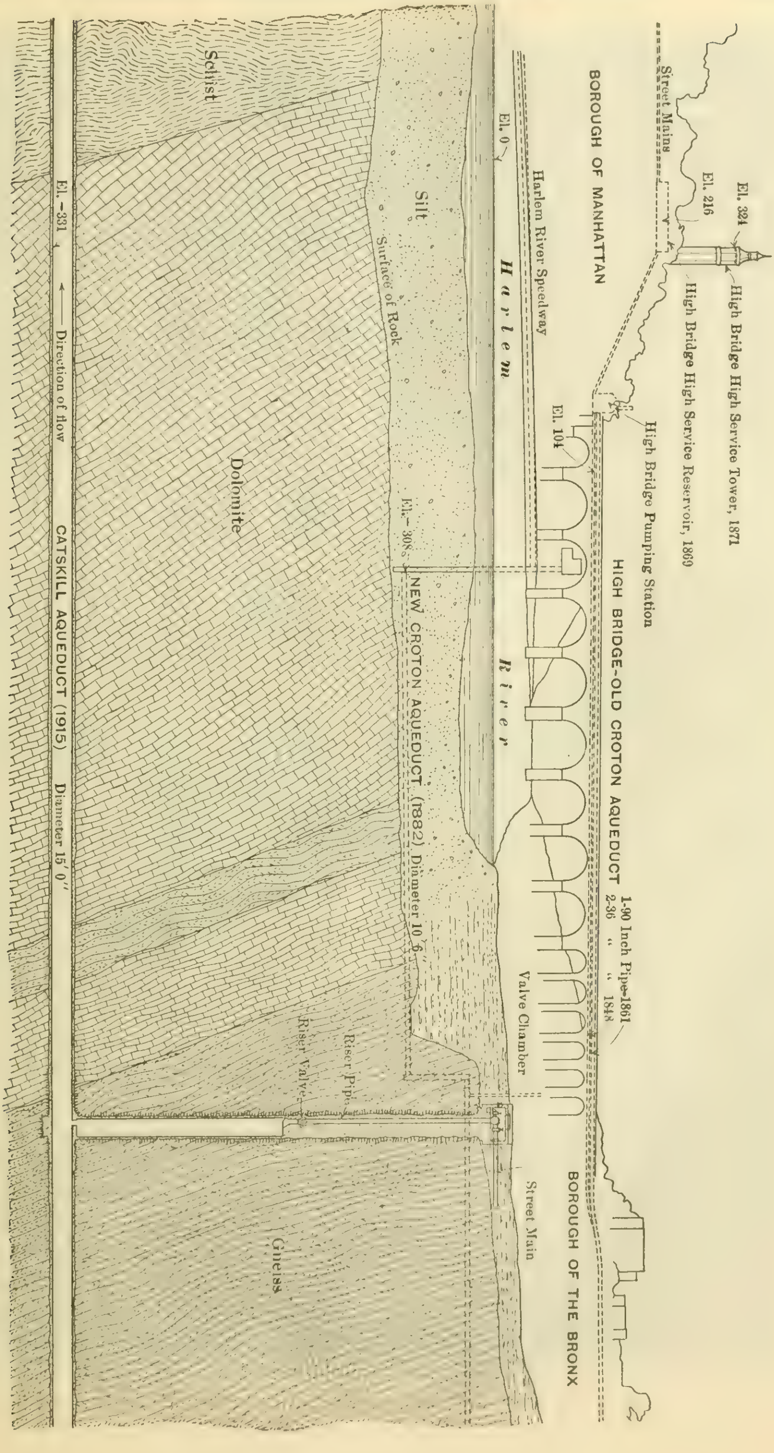

El. 324
High Bridge High Service Tower, 1871
El. 216
High Bridge High Service Reservoir, 1869
Street Mains
High Bridge Pumping Station
BOROUGH OF MANHATTAN
HIGH BRIDGE-OLD CROTON AQUEDUCT
1-90 Inch Pipe-1861
2-36 " " 1848
Harlem River Speedway
El. 0
El. 104
Harlem River
Silt
Surface of Rock
El. -308
NEW CROTON AQUEDUCT (1882) Diameter 10' 6"
Valve Chamber
Street Main
BOROUGH OF THE BRONX
Schist
Dolomite
Gneiss
Riser Pipe
Riser Valve
El. -331
Direction of flow
CATSKILL AQUEDUCT (1915) Diameter 15' 0"

FIG. 16.

Elevation — 200 and a weakened rock condition and decay to Elevation — 600, was regarded as so questionable in its behavior both for construction and permanence that it was determined to depress this section to Elevation — 700 in order to reach firm rock. On the Brooklyn side of the East River, the tunnel grade was raised again to Elevation — 250 to the terminal.

Fig. 17 shows the rock 700 ft. beneath Delancey Street. This rock is Inwood limestone, with complicated folding, crumpling, and faulting, and is cut through by a granite dike. The folding is characterized by remarkable crumpling varying from small plications of a few inches to great arches such as form the major ridges of the island and indicating a former deformation of the rock of considerable magnitude. Much trouble may be experienced in tunnels through folded rocks if they show marked fracturing, and careful attention must be given in such cases to the geological structure.

Observations on the results of construction and operation indicate that the deeper positions are the most successful. Athough Elevation — 700 would doubtless be excessive for the whole tunnel, the success of the work at the East River, together with difficulties that arose in certain of the shallower sections, have led to the conviction that the tunnel is nowhere placed too deep. There are weaknesses in all types of rock, and it is not the average condition but the weak spots which control the efficiency of the conduit under operating conditions. The behavior of the rock formations under construction and operating conditions has shown that the limestone formation at the depth of the tunnel has been a satisfactory type of rock, much more so than was expected. The difficulties expected from it were perhaps overstated, because of its behavior at the surface. There is no reason to believe that those parts of the tunnel where limestone forms the walls will be much less successful and permanent than other parts.

The banded Fordham gneiss formation has at some places proved to be unsatisfactory as a rock for tunneling, because of its tendency to break out in slabs more extensively than either the limestone or the schist. The schist which in ordinary exposure is strongly foliated, has proved to be a satisfactory formation. Its crumpled nature and the fact that the schistose structure stands at high angles in the ground, coupled with the additional fact that the tunnel is at sufficient depth to avoid superficial weaknesses, has furnished almost ideal rock conditions. This rock could be broken very true to the required lines, and it seldom presented structural difficulties or dangerous ground.

Considerable difficulty was experienced in driving through those rocks that exhibited a strong tendency to break into thin slabs, especially when this condition was developed in rock that lay nearly flat or crossed the tunnel at a very slight angle. The Fordham gneiss presented these conditions, and occasionally, the other formations. Where crush zones were encountered not only was the ground dangerous for working because of the tendency of blocks to drop from the roof, but in some places the inflow of water and the disintegration of the rock on exposure gave additional construction difficulties. At 106th Street, where the tunnel crossed a known fault line with a wide crush zone, the rock did not present any unusual features when the

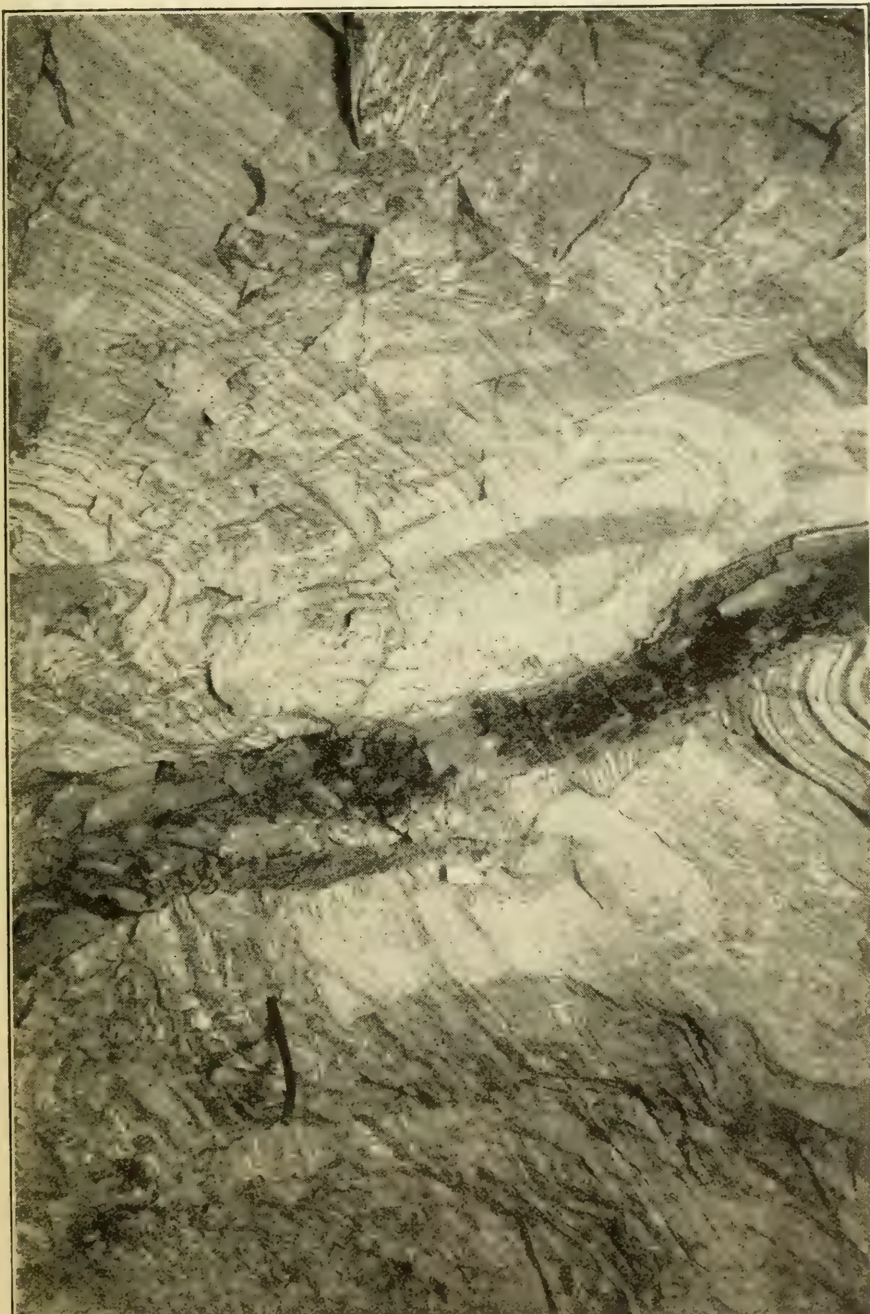


FIG. 17.—ROCK FORMATION 700 FT. BELOW DELANCEY STREET, NEW YORK CITY.

tunnel first penetrated it, except that it broke out in small pieces. Later, after exposure, the walls of the tunnel showed extensive disintegration and softening. At 106th Street, a heavy steel shell was placed for 110 ft. through the crush zone.

A worse condition as far as excavation was concerned was in the crush zones beneath the 125th Street depression, and somewhat similar conditions were encountered in the vicinity of 146th Street. At these places, the rock was broken more in blocks than at 106th Street and these blocks would drop out. In the vicinity of Jerome Park and elsewhere, some of the joints in the rock were water-bearing, one of which furnished for a time as much as 500 gal. per min. It was thought at first that this might connect with the reservoir, but the later behavior seemed to indicate that the chief water supply was local and connected only with the open joint system of the rock and the overlying soil.

Along the course of the tunnel joint systems of considerable prominence were encountered at many points. As a rule, these joints were not heavily water-bearing, but it was recognized that water would be lost through them, unless they could be closed. When the hydrostatic test was made leakage developed near Madison Square, New York City. This section was repaired by lining the tunnel for some distance with sheet copper and by grouting the rock joints. No other sections of the tunnel have thus far developed weaknesses of this kind and its operation is considered successful.

Staten Island Development

Water from the Catskills is carried to Staten Island in steel pipes from Shaft 24. A cast-iron pipe was laid through the silt of New York Bay at The Narrows. A short tunnel in serpentine rock conducts the water to Silver Lake Reservoir on the high ground of Staten Island. The bed-rock is serpentine, much fractured at the surface, and of complex internal structure, but essentially substantial and water-tight at a moderate depth. The exposed parts are considerably broken and allow the circulation of water through the network of fractures or joints. This rock, however, is covered with drift, of which part is heavy substantial till and part assorted gravel and sand.

The site chosen for the reservoir is that of an original natural lake. It is, however, surrounded by glacial deposits, and explorations showed that these deposits, both at the southerly outlet and at the westerly side, are comparatively deep and variable in quality. The borings, however, indicated such a succession of interfingering or interlocking of porous and of impervious portions, that it was thought practicable to depend on this ground to hold water. The dike at the westerly outlet was constructed with a core-wall that reached to bed-rock, but did not extend the entire distance across the depression. The southerly outlet was so deep that no attempt was made to put a core-wall to bed-rock.

Some leakage developed under operating conditions; both to the west and to the south, the water travels in a roundabout way through the interlocking irregularly distributed porous parts of the drift, evading the more substantial obstructing dikes and impervious material. Undoubtedly, greater

reliance was placed on the quality of the drift and the water-tightness of the floor than conditions warranted.

Long Island

Originally, the development undertaken by the Board of Water Supply included a project for the development of additional supplies from Long Island sources. For many years the City of Brooklyn had secured part of its water from surface streams and wells many miles beyond the city limits. It was intended to develop the underground supply of Suffolk County and considerable progress was made before restrictive legislation caused the temporary abandonment of the Long Island project.

Underground supplies alone were sought, which, it was expected, might be increased by obstructing the run-off from some of the small streams in such a way as to give greater opportunity for the water to soak into the soil. The essentials of this project, therefore, have to do with the quantity and behavior of recovery of ordinary well waters and the underground conditions which govern them.

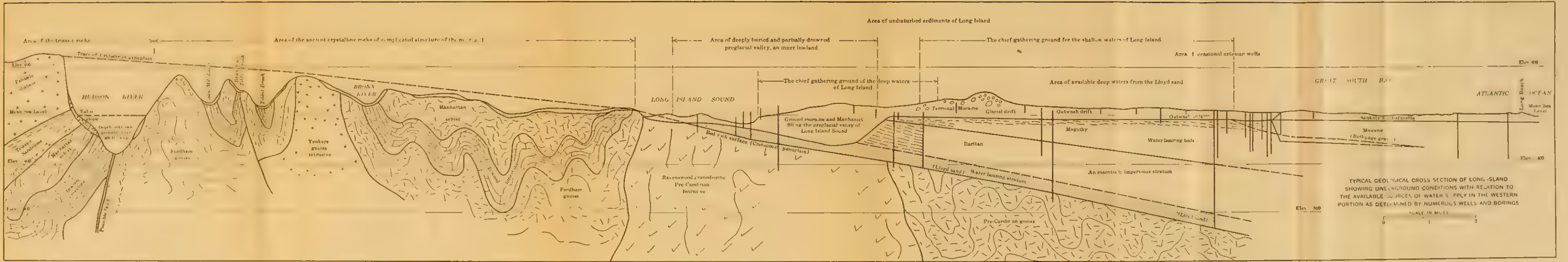
The coastal plain formation shown on Plate XXIII, together with the glacial deposits on Long Island, overlie the ancient rocks and contain the porous members which are the main sources of water supply.

Immediately beneath the glacial drift of Long Island are a series of sedimentary sands and marls, and clay dipping gently toward and beneath the sea. This whole series, in turn, lies on a uniform base of crystalline rock, the old eroded surface of which slopes in the same direction. None of the overlying strata extends farther inland than Long Island Sound and only the lowermost reach that far, because later erosion has beveled across these beds, so that if the glacial drift were scraped off, one could walk across the exposed layers one after another from Long Island Sound to the ocean. Thus, all of them are open to the entrance of percolating water along their entire landward extension.

All the layers are heavily covered, however, with glacial drift including mixed morainic materials and an immense quantity of assorted gravel and sand. This glacial drift practically covers everything on Long Island, and its extreme porosity, which is its most striking characteristic, is also a most important factor in the problem of water supply, as ordinary rain water soaks into and through this drift cover and enters the underlying beds in great quantities. All these materials, both the glacial drift and the underlying sedimentary beds, are water-bearing, but because of their irregular surface and porosity, the depth to permanent water differs considerably.

Water obtained from these underground sources comes both from the drift and from the sedimentary beds at many different levels. Most of the supplies used are shallow and belong chiefly to the glacial drift. Deeper wells penetrate successive water-bearing sedimentary beds, some of which furnish a high grade and abundant supply. A particularly prominent source of high-grade water is known as the "Lloyd sand", which is one of the deepest layers, and wells penetrating this stratum sometimes give Artesian flow. Many

PLATE XXII
PAPERS, AM. SOC. C. E.
SEPTEMBER 1922
BERKEY AND SANBORN ON
ENGINEERING GEOLOGY,
CATSKILL WATER SUPPLY



TYPICAL GEOLOGICAL CROSS SECTION OF LONG ISLAND SHOWING UNDERGROUND CONDITIONS WITH RELATION TO THE AVAILABLE SOURCES OF WATER SUPPLY IN THE WESTERN PORTION AS DETERMINED BY NUMEROUS WELLS AND BORINGS

SCALE IN MILES
0 1 2

of the strata are too closely textured to permit ready movement of water. All the waters are of surface or rain water origin. None of them comes from distant sources and the supply is limited to the quantity of such percolation. On both the north and south margins of the island, salt water encroaches on the fresh-water supply, the encroachment depending on the quantity of withdrawal.

The method of development, therefore, involves the sinking of wells into these water-bearing materials and developing this important supply. A large project would necessarily remove considerable of the underground water and would lower the ground-water level at the points of extraction. This feature was emphasized by the objectors to the plan, who finally caused temporary abandonment of the project. The ground-waters of Long Island are high grade and a large supply could be made easily available. It is near New York City, and development would cause a minimum of disturbance to other kinds of ownership and interest. Ultimately, this source will be used on a much larger scale, as the city's demands grow. It is the only near-by source of any consequence and also the only one capable of so large a development at small expense. The conditions governing this supply and the methods of recovery and control are certain to receive a great deal of attention in the near future.

Acknowledgments

The development of the Catskill Water Supply was begun in 1905 and was conducted by the Board of Water Supply, New York City. The Engineering Staff was under the direction of J. Waldo Smith, M. Am. Soc. C. E., Chief Engineer, until July, 1922; Thaddeus Merriman, M. Am. Soc. C. E., formerly Deputy Chief Engineer, is now Chief Engineer; John R. Freeman, President, Am. Soc. C. E., William H. Burr, M. Am. Soc. C. E., and the late Frederic P. Stearns and Alfred Noble, Past-Presidents, Am. Soc. C. E., were the Consulting Engineers. Mr. J. Waldo Smith is now also Consulting Engineer. Professors W. O. Crosby and J. F. Kemp, and Dr. Berkey were the Consulting Geologists. Acknowledgments are made by the writers to all who have contributed to this work.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

TESTS OF CONCRETE IN SEA WATER

By L. C. Wason,* M. Am. Soc. C. E.

Technical Papers Presented at the Annual Convention, Portsmouth, N. H., June 21st, 1922†

In the summer of 1901, the writer was frequently at the Charlestown Navy Yard, and observed the building of Pier No. 1. The concrete, of which this pier was constructed was mixed so dry that, when it was tamped in place, no water showed on the surface. In a few years, this pier showed serious defects, and the writer and his associates discussed with various engineers the cause of this early failure. Many reasons were advanced, but no conclusion was reached. This discussion was broadened through the technical press without obtaining a satisfactory answer, and it was finally decided to investigate the cause. After extended publicity and correspondence, a series of twenty-four test specimens, 16 in. sq. by 16 ft. long, were made of various qualities of cement. Three different proportions of cement, sand, and broken stone, and three different quantities of water were used. These specimens were made during the first two weeks of January, 1909, and were immersed in the sea at the Charlestown Navy Yard, in the last week of February, 1909.

They were suspended so that more than 3 ft. of each specimen at the top would seldom be wet and, presumably, never be immersed, whereas about $3\frac{1}{2}$ ft. projected below mean low water, and, therefore, would never be uncovered.

The details of the making, the progress, and the reports of the condition of these specimens have been described in two pamphlets entitled, "Aberthaw Tests on Concrete in Sea Water", issued in 1914 and 1920, respectively, in a number of articles in the technical press, and most fully by R. E. Bakenhus, M. Am. Soc. C. E.‡ Reference is made to these sources for full details. Only

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* Pres., Aberthaw Constr. Co., Boston, Mass.

† Continued from August, 1922, *Proceedings*.

‡ *Transactions*, Am. Soc. C. E., Vol. LXXXI (December, 1917), p. 645.

such extracts from those data will be made as are necessary to make this paper intelligible.

After 13½ years of study of these specimens, the writer believes it is possible to make some tentative deductions on the cause of failure and suggestions for design so as to make future structures as nearly as possible proof against disintegration by sea water.

The conditions in Boston Harbor are probably as severe as in any harbor of the United States. The specimens are subjected to considerable tide run, attacked by waves, abrasion from floating objects, freezing during severe winters, and attack from impurities, chemical or otherwise, present in sea water.

In April, 1914, the Navy Department put into commission fuel-oil pipes adjoining these specimens. Oil spilled on the sea has heavily coated them from near their tops to low tide. The writer believes this coating retards the action by the sea water and, therefore, will lengthen the time required for this test, which, however, will not destroy its value.

At low tide, on May 22d, 1922, the writer made an examination of the specimens. No appreciable change could be observed from the condition as described in the 1920 report of the Aberthaw Company, and the order of deterioration was the same as that given by Capt. Bakenhus in his report of 1917.

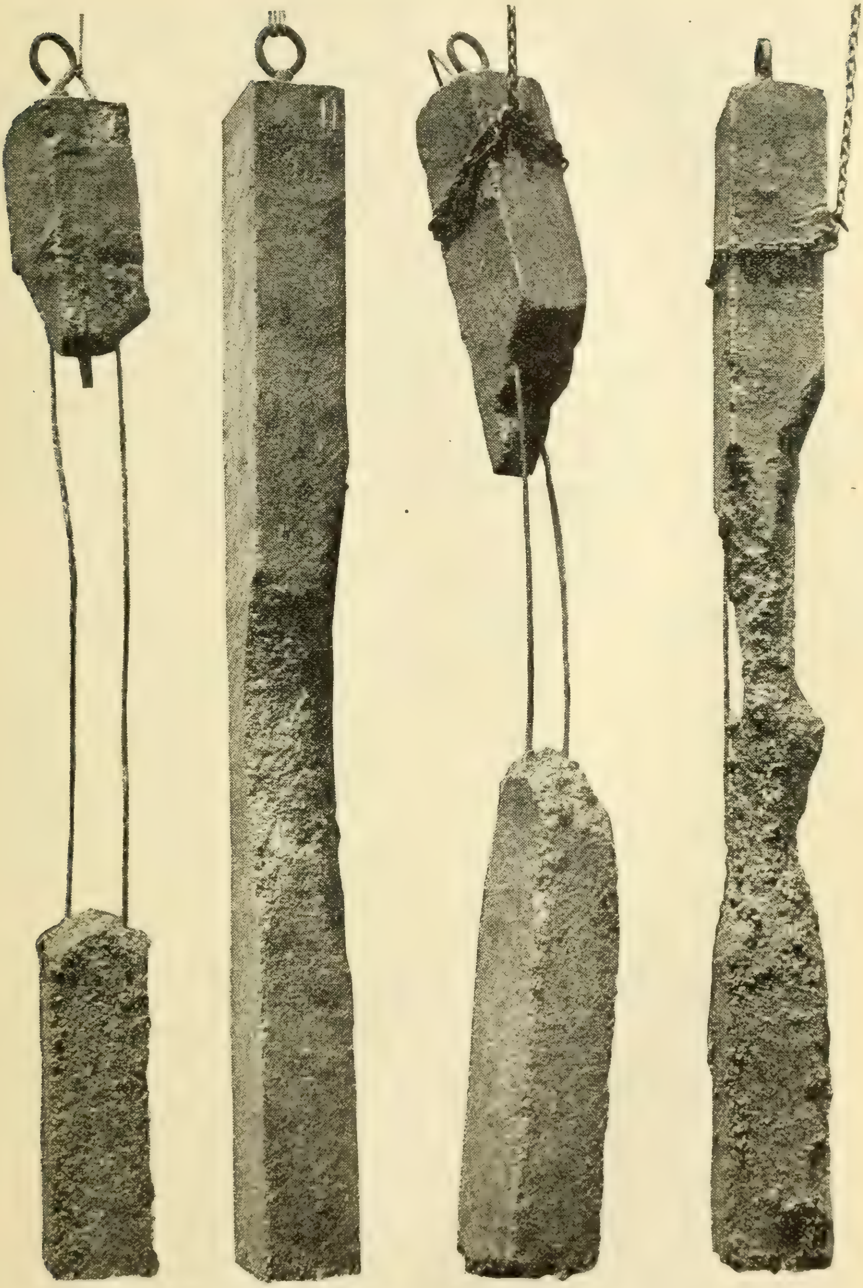
Two of the twenty-four original specimens, Nos. 19 and 21 have been lost; and five are in poor condition and may be considered to have failed. These five, which are Nos. 7, 11, 13, 22, and 23, were made of 1:3:6 concrete. Capt. Bakenhus makes nine classes, or degrees, of failure, placing No. 7 in the worst class, Nos. 22 and 23 next to the worst, that is, in Class 8, Nos. 11 and 13 in Class 6, fair condition.

Specimen No. 7 was mixed dry, whereas the other specimens were mixed wet. Specimens Nos. 1, 4, 8, and 9 show some deterioration. Nos. 1 and 4 are of rich proportions, but mixed dry, whereas, Nos. 8 and 9 are of plastic and wet mixtures, but of lean proportion. The remainder, Nos. 2, 3, 5, 6, 10, 12, 14, 15, 16, 17, 18, 20, and 24 are in fairly good condition.

On May 24th, 1922, Specimens Nos. 7, 11, 22, and 23 shown on Fig. 8, were removed for testing. No. 7 was made of three average, normal Portland cements, Vulcanite, Alpha, and Giant, in equal parts, thoroughly mixed, and then repacked in bags for use in mixing the concrete. No. 11 was made of Blanc (white Portland cement), very wet. No. 22 was made of 90% of the same cement as No. 7 and 10% of hydrated lime, very wet. No. 23 was made of cement like that of No. 7, plus Sylvester solution of soap and alum, very wet.

When the specimens were removed from the water they had, at the tops, about ¼ in. of gummy, sticky adhesion of fuel oil and dirt, which, toward the low-water mark, became thinner with a harder, somewhat glossy surface.

No oil could be noted below the low water-line, but the specimens were coated with live mussels, which indicated that the impurities of the water were chiefly on the surface and were not sufficient to kill marine life.



No. 7. No. 11. No. 22. No. 23.

FIG. 8.—TEST SPECIMENS.

Some of the specimens had previously been cracked in being removed from the water and some pieces that broke off at the cracks showed a slight brownish discoloration, which indicated that the oil had not penetrated very deeply or in any volume into the cracks. No evidence of penetration of oil below the surface of even the poorest specimens could be detected at fresh fractures of the concrete. Discoloration was not more than $\frac{1}{32}$ in. deep. In all these specimens, the parts most damaged, namely, those near mid-tide, showed a rather disintegrated and soft concrete.

The specimens were cut to approximately square faces, the length of the test pieces being more than twice the width of the cross-section. The steel reinforcement was cut off and burned below the surface. The test pieces were then faced to a flat surface resembling terrazzo.

The top end of Specimen No. 7 was so short and so badly cracked that it was impossible to obtain a test piece larger than about 8 by 8 in. by $15\frac{1}{2}$ in. All the others were of the full cross-section and about 3 ft. long.

Through the courtesy of Professor H. W. Hayward, M. Am. Soc. C. E., they were tested at the Massachusetts Institute of Technology on June 7th, 1922.

TABLE 8.—Actual Bearing Area of Test Specimen.

No. of piece.	Bearing.	Area, in square inches.	Average area, in square inches.
7 Top....................	Top	51.8	
	Bottom.	62.8	57.3
7 Bottom..................	Top.	232	
	Bottom.	230	231
11 Top....................	Top.	236	.....
11 Bottom.................	Top.	240	.....
22 Top....................	Top, poor.	200	.....
	Bottom.	215	207.5
22 Bottom.................	Top.	217	
	Bottom.	208	212.5
23 Top....................	Top, fair.	213	
	Bottom.	238	226.5
23 Bottom.................	Top.	221	
	Bottom.	224	222.5

A piece of blotting paper was placed on top of the first specimen and under both ends of the remaining specimens. From the impression made on these sheets, it was possible to obtain the net bearing area and the character of the bearing. The edges of the test pieces were irregular and, on some, the corners were broken so that it would have been difficult to obtain the bearing area by direct measurement. In Table 8 is given the average bearing area of each end, which area is approximate only, and the writer is convinced that it is too large, rather than too small. The specimens were tested only to the point of failure. Cracks appeared longitudinally, and formed roughly two prisms the shape of an hour-glass. Reinforcing steel that was exposed after the tests, appeared to be bright. Specimen No. 7, the most porous one, was so broken after the test, that the reinforcing bar was removed. With the exception of three spots about $\frac{1}{4}$ in. in diameter which showed rust, the bar was entirely bright. This bar was from the lower end of the specimen which had been immersed for $13\frac{1}{4}$ years.

For chemical analysis, a sample was taken from the top of the specimens, one from the lower corner of the bottom specimen and one from near the center. Mr. Herbert L. Sherman, a cement chemist, co-operated with the writer in making chemical and physical analyses of the cement in the making of the specimens.

After a careful and complete analysis of three samples each from Specimens Nos. 7 and 23, and a thorough study of the results, Mr. Sherman reports that it is impossible to draw any conclusions.

TABLE 9.—Crushing Load on Sea-Water Test Specimen.

No. of piece.	Original cross-section, in inches.	Area, in square feet.	Length of test specimen, in inches.	Actual section, in inches.	Total load, in pounds.	Load, in square inches, actual section.	Ratio of strength, top to bottom.
7 Top........	15⅞ by 16⁹⁄₁₆	1.82	15½	57.3	157 300	2 750	0.82
7 Bottom...	15⅞ by 16⁹⁄₁₆	1.82	35½	231	778 800	3 375	
11 Top........	16 by 16¾	1.86	36	236	750 200	3 180	0.93
11 Bottom....	16 by 16¾	1.86	37	240	823 900	3 435	
22 Top........	15⅞ by 16⅜	1.80	30¾	207.5	463 100	2 235	0.92
22 Bottom....	15⅞ by 16⅜	1.80	36	212.5	562 100	2 645	
23 Top........	16³⁄₁₆ by 16¼	1.82	32½	226.5	391 600	1 730	0.91
23 Bottom....	16³⁄₁₆ by 16¼	1.82	33¾	222.5	424 600	1 907	

The result of the crushing test is given in Table 9. The original cross-section is copied from the earlier report, and is not a scaling of the specimens at the present time. It will be noted that the normal mixture of concrete shows results as good as could be expected of any concrete of this mixture and age. It will be noted also that the lower end of each of the four specimens was stronger than the upper end.

Omitting Specimen No. 7, from which only a small sample could be tested and which, therefore, may not be directly comparable with its own bottom, the other three show the strength of the top to be about 92% of that of the bottom. This indicates that there is a common law as to the condition of the concrete when permanently wet as compared with dry.

The following summary of tests on 1 : 3 : 6 concrete mixed dry, plastic, and wet, on four brands of cement, cured in air for 1.6 to 1.75 years is given for comparison with laboratory specimens. The data on these specimens, which were 12-in. cubes, was taken from the Annual Report of the State Engineer of New York for the fiscal year ending September 30th, 1897. Fifty-two specimens were crushed at the Watertown Arsenal, the dry specimens being 9% stronger than those from plastic or wet concrete:

Highest crushing strength per square inch.........2 887 lb.
Lowest " " " " " ....1 716 lb.
Average " " " " " ....2 095 lb.

In 1912, the writer built, in Portland Harbor, a fish pier that consists of a wharf, supported by concrete piers about 4 ft. square, with a heavy floor forming the wharf platform, on which a fish house was built. Most of these piers were built inside a coffer-dam, and, therefore, were cast dry and allowed to set more than a month before being subjected to the tidal action of the sea.

The two rows of piers nearest the shore, being out of water except during high tide and never being immersed more than about 3 ft., were cast between tides. An examination of these piers was made on May 25th, 1922, at which time they were ten years old. All the piers cast within the coffer-dam appeared to be in first-class condition, whereas those cast between tides showed some signs of deterioration below high-tide line.

In 1902, a series of concrete specimens was made in order to test the protection of steel from corrosion. The concrete was of 1:3:6 proportion, with the expectation that it would be porous. The blocks were 4 in. square and 12 in. long, and had a ½-in., square twisted steel bar, 16 in. long, through the center, that projected at both ends.

At Fort Warren, the War Department, immersed one series of these specimens in sea water and, after 3 years' testing, the remainder of this series was lost.

The second series was given to the Chief Engineer of the Metropolitan Sewerage Commission, and were immersed in a trunk sewer. After seven years, the remainder of this series was lost.

The third series of specimens was buried in ground that was always damp and at times was saturated with water. After being twenty years in the ground a specimen from this series was removed and split open. The steel was bright in every specimen of all three series where the cement was in close contact with it; rust was present where there were voids. When the bars were originally embedded, they were coated with hard rust, but no scales. These results indicate that cement will protect steel from corrosion in unfavorable conditions.

Although it is not time to draw final conclusions from these series of tests, and although the series is not sufficiently comprehensive to prove a general rule for all cases of immersion of concrete in sea water, it is thought that some conclusions are now justified, and ought to be helpful to those designing marine structures.

It appears, first, that the mechanical action of the elements is much more vital than the chemical action. The densest specimens show the least wear. The porous specimens which were built with the expectation that they would soon disintegrate, have done so.

Chemical action must be considered. The specimens in which the cement was low in alumina, both of lean and of rich mixtures, are in good condition. Those that had foreign ingredients (Nos. 22 and 23), of hydrated lime and Sylvester solution, show serious weakness, whereas one specimen containing 5% of clay as filler to make the concrete dense, is still in quite good condition.

The question of the quantity of water used in mixing must be considered. In a paper* by Mr. Dan Patch, photographs are shown of the specimens arranged in three horizontal rows, in the order of the quantity of water used in mixing, and superimposed is a curve showing resistance to compression and to wear as determined by the Research Laboratory of the Lewis Institute of Chicago, Ill. The condition of the specimens shown in these photographs indi-

* *Engineering News-Record,* March 3d, 1921.

cates that those containing from 9 to 10% of water are in better physical condition than the very dry or the very wet specimens.

If good workmanship is observed in the placing of concrete in forms, excess of cement and mortar is brought to the surface and produces a skin which, until abrasion has removed it, resists very well the action of sea water. The concrete is not as durable in resisting wear as this skin.

Specimens made of the poorer materials, which fail the earliest in their lower portions, due to tidal action, have proved durable if permanently immersed. An explanation of the reason for the upper end of the specimen showing less strength than the lower end may be due in part to the matter of suspension. In order to handle the specimens readily, $\frac{5}{8}$-in. square twisted steel bars were extended about 2 in. from the surface the full length at opposite corners. In the center of the specimen, a hole was cored into which was grouted a hook with a shank about 3 ft. long, by which the specimens were suspended. The weight of the specimen produces a tension of about 100 lb. per lin. in. in the upper 3 ft. This condition may have produced porosity, or invisible cracks, through which weathering took place. The upper end was subjected to yearly variations of temperature of probably 100° Fahr.—sometimes, to changes of many degrees within a few hours—at times to a film of ice on the surface, and to a slight degree of abrasion of floating objects in the water.

It seems safe to conclude that if rich concrete is made from a good quality of cement, of normal composition, or low in alumina, and the material is thoroughly mixed, using 9 to 10% of water, and placed in the dry with careful spading to assure a dense surface, that durability in sea water can be assured unless the specimen is subjected to considerable abrasion, in which case it would be wise to face the concrete with a protective coating within the limits of the rise and fall of the tide. Below low tide, and above high tide, concrete as described is a practical, satisfactory, and proper building material.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications.

TENTATIVE PLAN FOR THE CONSTRUCTION OF A 780-FOOT ROCK-FILL DAM, ON THE COLORADO RIVER, AT LEE FERRY, ARIZONA

Discussion.*

By Messrs. C. R. F. Coutlee, H. B. Muckleston, Edwin H. Warner, F. A. Noetzli, Kirk Bryan, Arthur P. Davis, J. C. Stevens, J. H. Quinton, Ernest H. Baldwin, and C. S. Jarvis.

C. R. F. Coutlee,† M. Am. Soc. C. E. (by letter).‡—Rock-fill dams are perhaps the most useful appliances in engineering, now that water power has become such a prominent branch of that science. They have been used in India for a long time, the up-stream face being staunched by depositing, first, stone of one-man size, then macadam size, and, finally, sand. Two parallel rock-fills with an earth center, as used at Panama, is a splendid arrangement.

At Kenora, Ont., Canada, there is a rock-fill dam with sluice-ways closed by movable stop-logs. It was built by the late Sir John Kennedy, M. Am. Soc. C. E., 30 years ago, the granite rock being deposited in the rapids without particular care. The up-stream face is neither paved nor staunched, and the leakage has remained about constant. The slope through the dam extends from the water surface above to about 1 ft. higher than the surface of the water below. The head is 18 or 20 ft., the slopes are 1:1, and the width 3 ft. above water is 6 ft.

The Georgian Bay Canal Project, Ottawa River, included many large rock-fills which are described in the Report for 1908 of the Public Works Department of Canada. In connection with the Ottawa River storage, several rock-fill dams were built from 1909 to 1912.

* This discussion (of the paper by E. C. La Rue, M. Am. Soc. C. E., published in April, 1922, *Proceedings*, but not presented at any meeting of the Society) is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† Ottawa, Ont., Canada.

‡ Received by the Secretary, May 8th, 1922.

At the foot of Quinze Lake, the dam is more than 1 mile long and 45 ft. high in middle channel. The embankment was made from each side and closed in mid-stream with a flow of 5 000 sec-ft. running. Large rocks were carried down stream at first, but soon they came to rest and others jammed against them, until gradually the fill grew up stream. Part of the dam, more than 30 ft. high, was deposited on a swamp. The slopes are 1.5:1, with a width of 10 ft. at 5 ft. above full reservoir.

At Kipawa River, at the north end of the lake, a rock-fill was deposited across a crevice in the granite about 100 ft. wide, through which 1 000 sec-ft. poured in a rapid. At the south end of Kipawa Lake, another rock-fill, 500 ft. long, was deposited on bare rock. No attempt was made to staunch any of these dams. At the north end of Kipawa Lake, the leakage is 300 sec-ft., and at the south end about 200 sec-ft., the maximum head approximating 15 ft.

At the Timiskaming Dam, four concrete sluice-ways were scoured under during the spring flood of 1912, and the piers settled down into a sand pocket. Satisfactory repairs were made by filling in the gap with rock. The depth was 25 ft. and the head about 15 ft. Down stream from this dam, a flow of 70 000 sec-ft. scoured out a hard boulder bottom to a depth of 20 ft. below the sill, for a width of 400 ft. This was filled with 30 000 cu. yd. of loose rock, into which the next high flow scoured 15 ft. in depth. Loose rock was again used for filling, and further scouring has not taken place. Descriptions of these works are given in the Ottawa River Storage Reports of the Public Works Department of Canada, for 1913 and 1915, which, although out of print, are available in libraries. In constructing the branch of the Canadian Pacific Railway from Toronto north to Sudbury, rock embankments were made to sink into muskeg swamps with considerable certainty as to alignment.

A rock-fill becomes part of the geology of the country, it will not overturn nor slide on its base, and it will stand over-topping for some time. It is immensely strong, but leaky. To staunch the face, the voids should be gradually reduced with stone decreasing to macadam size and then a covering of earth should be applied at slope of from 3 : 1 to 7 : 1. Brush mattresses are not desirable for staunching, as they bridge voids and eventually break suddenly. At Frank, Alberta, Canada, the great rock slide, 2 miles long and 2 miles wide, occupied the whole bed of the middle fork of the Old Man River. Without gathering much head, the small river, however, has been able to seep through.

A great rock-fill dam might be constructed across the St. Lawrence River, near Rivière du Loup, requiring 70 000 000 cu. yd., which could be deposited after twin locks, similar to those at Panama, had been built in Hare Island. The sluice-ways to pass 800 000 sec-ft. could also be constructed in the dry before any rock was deposited. This would bar out the tide, leaving the upper river fresh water, with a current in the outward direction only. There would be no more tidal fluctuation or choking by tide-borne ice, and a 40-ft. depth, without flooding, would be secured. In a similar manner, a rock-fill, 400 or 500 ft. wide on top, could be built across the Hudson River between New York

and New Jersey, which would keep the river at a constant level as far as Albany, N. Y.

H. B. MUCKLESTON,* M. AM. SOC. C. E. (by letter).†—This paper describes a proposal to dam the Colorado River by artificially creating an enormous landslip from the canyon walls. Except for the artificial feature, the proposal is not without precedent.

The same thing occurred naturally in 1893 on the Birahi-Ganga, a small stream in India. In this case, the dam was about 900 ft. high, 11 000 ft. wide at the base, and 2 000 ft. wide at the top. The catchment area above the dam was small, about 90 sq. miles, so that the discharge cannot have been very great. Nevertheless, the dam went out as soon as it was topped.

In view of the author's proposals for staunching his dam, it is interesting to learn that the Gohna Lake Dam, referred to, leaked 350 sec-ft. long before it was topped. A full account of this failure has been published.‡

EDWIN H. WARNER,§ M. AM. SOC. C. E. (by letter).||—The author presents a plan for a rock-fill dam 780 ft. high and greater in magnitude than any dam of which there is a record. The type proposed is archaic, developed when low first cost was a necessity, which necessity does not exist in the case under consideration.

The profile, Fig. 3,¶ is conservative; the notation on it "rock-fill made impervious" is reminiscent of "let there be light and there was light". With this notation in effect, and the author's statement that there shall be no overtopping of the dam by flood waters after the dam is completed, it is not apparent why the toe should be carried 1 mile down stream. The profiles of rock-fill dams illustrated in the "Design and Construction of Dams", by Edward Wegmann, M. Am. Soc. C. E., show no such exaggeration of the down-stream slope.

The author's first step in construction is to drop 1 000 000 cu. yd. into the bed of the stream, making a dam 250 ft. high, "this will settle 60 ft. through sand and silt which will be forced up". The probability that this settlement will occur does not seem great. Much greater, however, is the probability that, as he says, a flood of 100 000 sec-ft. will strew his rock down stream leaving a dam 100 ft. high; the "blessing in disguise" part of the operation as "leaving a solid foundation on which to build" seems somewhat problematical both as to the "blessing" and the "solid foundation". The next step is dropping 20 000 000 cu. yd. in one shot, on top of the first 1 000 000 cu. yd., "thus forming a mudbank immediately up stream" and "cutting off the irrigator's supply for from 10 to 70 days" until the mudbank is overtopped and washed away. The author states that "this might result in serious damage to the crops, and an understanding should be made with the irrigation interests that they may take proper steps to protect their crops". He does not suggest an arrangement; it

* Chf. Engr., Lethbridge Northern Irrig. Dist., Lethbridge, Alberta, Canada.

† Received by the Secretary, May 6th, 1922.

‡ Records of the Public Works Department of India, No. 324; *Journal*, Soc. of Arts, London, March, 1896; and, also, "Water Power", by the late J. P. Frizell, M. Am. Soc. C. E., p. 250.

§ Cons. Engr., San Francisco, Calif.

|| Received by the Secretary, May 22d, 1922.

¶ *Proceedings*, Am. Soc. C. E., April, 1922, p. 840.

could take two forms, namely, the purchase of the crops on 400 000 acres at a cost not much in excess of his estimate of the cost of a rock-fill dam, or supplying water from some other source. Neither of these alternatives seems to be quite practicable, so, perhaps, it is best to be content with the possibility that the "mudbank" will not form, or, if it does, it will not make the complete closure suspected of it.

The author's estimate of 10 cents per cubic yard for blasting 50 000 000 cu. yd., seems to be low when viewed from the cost of explosives alone, and his expectation of landing his rock where he wants it, without rehandling, is negatived by his later statement that "it is impossible to determine just how the rock will fall".

The author "believes the dam can be made water-tight", and states that "there will always be seepage through the dam". To secure water-tightness, he assumes that the graded material, later introduced, will find its appointed place in a structure extending 1½ miles along the river. Perhaps it will; who knows?

The author concludes that the dam will cost little more than half that of a concrete dam, the cost of which he places at $50 000 000. Having assigned $5 000 000 as the cost of the rock-fill, it would be of interest to know what items enter into the remaining $20 000 000.

As a final, or, perhaps, more properly, first point in the matter of the author's design and construction methods, there is nothing advanced to satisfy the bond-buyer's engineer, who is obsessed by a curiosity as to what is to be done with the money his people are asked to furnish; he insists on facts and, at times, declares he can furnish his own opinions, which, being his own, satisfy him. That his opinion would be unfavorable to a rock-fill dam, 780 ft. high, is certain, even conceding as does the writer, that water-tightness is not, beyond reasonable limits, an absolute necessity.

His opinion would likewise be unfavorable to a concrete dam of similar height, since the unit stresses in the concrete would exceed the present limits of good practice. The only dam that will meet his approval, is a gravity type, the lower section of which will be mammoth rubble laid in cement mortar and carried up to a point where concrete can be safely used. The author's splendid monograph "Colorado River and Its Utilization",* furnishes data which point to a lesser height of dam than that proposed in this paper.

The mean annual flow of the Colorado at Lee Ferry is 15 000 000 acre-ft., but in order to satisfy fully all irrigation needs, 13 000 000 acre-ft. are required. The storage of 25 000 000 acre-ft. will give proper regulation and, with a dam approximately 450 ft. high, 800 000 h. p., which is about California's present total hydro-electric installation, can be developed.

The present and future value of property below Lee Ferry makes imperative the adoption of a dam of the gravity type, because it is the only type which will have the approval of the farmer, the bond-buyer's engineer, and the Federal and State regulatory bodies. The writer holds firmly to the opinion that an arch dam can be designed and built, which will be as secure against failure as

* Published as *Water Supply Paper No. 395*, by the U. S. Geological Survey.

the gravity dam, but consideration of this type is precluded by the fact that agreement in this opinion is not to be had from the several parties at interest.

If the author finds less constructive criticism in the foregoing than he asks for, he may find contentment in this, that both he and the writer are dealing largely in opinions on a matter which greatly transcends present knowledge; hence, each may hold to his own without undue prejudice.

F. A. Noetzli,* Assoc. M. Am. Soc. C. E. (by letter).†—Hydraulic engineers of the West are keenly interested in the deliberations of the Colorado River Commission which, under the leadership of Herbert Hoover, M. Am. Soc. C. E., has accomplished, during the recent months, a great deal toward smoothing out the conflicting interests of the various border States interested in the control and utilization of the waters of the Colorado River. In view of the fact that, by providing adequate reservoirs for storing the flood waters of the river at the various excellent reservoir sites on the main river and its tributaries, enough water appears to be available to satisfy, in every State concerned, all reasonable claims for irrigation and power for generations to come; it is to be hoped that the Colorado River Commission will soon be successful in initiating the construction of a large dam on this river.

At present, about 14 000 000 acre-ft. of water, out of an average of 16 000 000 acre-ft., is wasted annually into the Gulf of California. This would be enough water to irrigate at least 3 000 000 acres of land in addition to the area already irrigated from the river. According to the author, "more than 4 000 000 continuous horse-power may be developed between Green River and Boulder Canyon." Such figures should convince one that most of the present quibbling, with regard to sacrificing the rights of certain States for the benefit of others, has few engineering facts on which to rely.

Mr. La Rue's excellent paper will be welcomed by many engineers, as it affords an opportunity to discuss the feasibility of a large dam on the Colorado River. The thorough investigation of the whole project, made by the U. S. Reclamation Service, and more particularly the surveys and borings at the Boulder Canyon Dam site, would appear to have furnished already enough information to warrant the conclusion that the construction of a high dam across the Colorado River is feasible.

The author suggests the construction of a rock-fill dam by blasting down the canyon walls. In order that the discussion might be based on definite dimensions, he chose the Lee Ferry site, without, however, advocating this or any other specific project.

The suggestion of blasting enormous masses of rock from both sides of the canyon walls is fascinating, but it might prove to be a dangerous experiment on a stupendous scale. There exists no precedent on which to rely. All the evidence that may be gathered from past experience with rock-fill dams would indicate an almost certain failure. The writer is unable to agree with the statement of Mr. La Rue, that (in case of a flood of 100 000 sec-ft. passing over the dam to a depth of 8 ft.), "* * * to believe that after the flood, the dam would retain a height of 100 ft. above the average low-water level, seems

* Chf. Engr., Beckman and Linden Eng. Corporation, San Francisco, Calif.

† Received by the Secretary, June 5th, 1922.

more reasonable than that all of it would be carried away. * * *" In the past, whenever water has overtopped a rock-fill dam for 1 ft., or even less, the dam almost invariably was destroyed. The erosion, which may be assumed to have started at the crest, increased the depth and, therefore, the velocity of the flowing water. Since, as the author states, "* * * weight of bodies that can be moved by a current varies as the sixth power of the velocity * * *", the erosive action of the water overtopping a rock-fill dam increases at a tremendous rate, and soon will move also the largest sized rocks, inasmuch as the waters in the reservoir are discharged in addition to the flood flow that started the failure. Fig. 8 is a view from the new Lower Otay Dam, down the canyon through which the waters passed, that, in 1916, destroyed the former rock-fill dam. The photograph was taken by the writer early in 1922 and clearly shows the lighter colors of the deeper parts of the canyon, the side walls of which, for miles, were stripped of every loose particle, down to smooth solid rock. The force of the water will be appreciated from such a view. From a description of the failure of the Lower Otay Dam,* it appears that the reservoir of 40 000 acre-ft. capacity was emptied in 2½ hours. This corresponds to an average flow of nearly 200 000 sec-ft. for 2½ hours. In addition, the run-off from the water-shed amounted to about 35 000 sec-ft. The maximum flood peak was, therefore, probably in excess of 300 000 sec-ft., and the water rushed down the canyon with an average velocity of about 18 ft. per sec. Referring again to the possibility of the Lee Ferry dam being overtopped during construction, to a depth of 8 ft., by an unexpected flood of 100 000 sec-ft., it appears doubtful if more than perhaps a few of the largest blocks of the dam would stay within the area of the foundation.

Assuming, however, that the unfinished dam would retain a height of 100 ft. after the flood, it may be well to consider also the effect of the water that would be released from the reservoir between the 100- and 250-ft. level. The reservoir capacity between these two levels is several million acre-feet, and most of this water would be released during the first day, producing, together with the assumed flow of 100 000 sec-ft., a flood peak, below the dam, of probably more than 1 000 000 sec-ft. The effect of such a flow on the Imperial Valley and the bottom-lands along the Lower Colorado River would be disastrous.

However, it might perhaps be possible to devise a program of construction by which water would be prevented from overtopping the dam. The question is then narrowed down to the problem of making the dam water-tight during construction, as well as afterward.

Mr. La Rue suggests blasting about 20 000 000 cu. yd. of rock into the river channel with the first discharge of mines located on both sides of the canyon. It hardly can be assumed that this large quantity of rock would settle and spread evenly across the whole river, so as to form a more or less level barrier about 250 ft. in height, which would be the object of this first operation. At the 250-ft. level, the canyon is about 600 ft. wide, and, unless a great quantity of excess powder is used, the blasted rock would probably slide down the sides of the canyon, instead of being hurled a distance between 300 and 700 ft.,

* U. S. Geological Survey, *Water Supply Paper No. 426*, p. 25.

FIG. 8.—VIEW DOWN CANYON FROM NEW LOWER OTAY DAM.

measured horizontally, to the location where the designer of the dam would like it to drop. The danger evidently exists of a continuous low channel being formed approximately along the axis of the canyon through which the water might escape and destroy the dam before the level in the reservoir had reached the spillway tunnel. A rock-fill dam of the dimensions suggested by the author would no doubt be stable if it was possible to make the dam water-tight, or at least so to reduce the velocity of water percolating through the dam that it would not start erosion and blow-outs.

Past experience with earth and rock-fill dams has shown that, in general, for dams of considerable height, this is possible only by lining the up-stream face, or by providing a water-tight membrane, such as a concrete or steel sheet core-wall, or a puddle of clayey material, etc.

The author believes that "with the river under control the rock-fill can be made water-tight by sluicing fine material into the dam. * * *" The method proposed is ingenious. However, a combination of unforeseen conditions, such as arching of the loose material within the dam, and consequent abrupt and uneven settlements from the weight of the added rock in the building of the dam, might rupture the originally water-tight sand and silt cover and a blow-out might follow with disastrous consequences. The Colorado River silt is remarkably water-tight even in layers of a few inches, if the silt is precipitated from still or slowly moving water. However, if the water attains a velocity of 3 ft. per sec. or more, erosion takes place with great rapidity. Such action might occur if a silt membrane, on the up-stream face of the proposed dam, was ruptured by abrupt settlements within the dam.

Furthermore, it must be considered that, even if it should be possible, by sluicing, to make the dam water-tight for a working head of, say, 200 or 300 ft., the possibility still remains of flow and erosion starting when the water level in the reservoir would rise 600 or 700 ft. above the stream bed. The water pressure at the bottom of the full reservoir would be 43 700 lb. per sq. ft., or about 300 lb. per sq. in. Such a pressure is considered by conservative engineers as the limit for good concrete in masonry dams, and probably few designers would rely on a layer of wet sand and silt to sustain safely such load.

It would seem, therefore, that the construction of a rock-fill dam on the Colorado River involves a number of rather doubtful features which, during the construction of the dam, would hardly be conducive to sound sleep on the part of the responsible engineer, or the people living below the dam.

Arthur P. Davis, Past-President, Am. Soc. C. E., Director of the Reclamation Service, in his report to Congress, has demonstrated that the construction of a masonry dam on the Colorado River is safe and feasible. Hardly any dangers to life and property on the Lower Colorado River are involved in the construction of a masonry dam, and the final designs may show such a structure less costly than a rock-fill dam.

The problem to be solved, therefore, is at which of the various sites should such a masonry dam be built? Under present conditions, such a dam has to serve three purposes: flood control, irrigation, and the development of hydro-electric power.

Flood control of the Lower Colorado River is urgently needed. The great snowfall of the winter of 1921-22, over the drainage area of the river, may produce in 1922-23 exactly the dangerous conditions of which the inhabitants of the Imperial Valley are afraid and which such a dam would almost completely eliminate.

Even by permitting the upper States all the freedom desired in the irrigation of any or all of their land that may be entitled to it or that is susceptible of irrigation from this source of supply, enough water would still remain to irrigate 1 000 000 or 2 000 000 acres of additional land in Arizona, California, and Mexico.

Between 500 000 and 1 000 000 hydro-electric horse-power may be developed economically as a by-product. This is more than the market may possibly absorb for many years within economical distance of distribution. According to the author's figures there are, in addition, more than 4 000 000 h. p. capable of development between Green River and Boulder Canyon, enough for generations to come. In view of these facts, it is to be hoped that the various States concerned will soon come together for united action and empower the Federal Government to proceed with the construction of a dam on the Colorado River. The embracing of a maximum part of the water-shed to afford the greatest possible protection from floods, the closer proximity to the large area of irrigable lands, and the closeness to the market for power, all favor the building of a dam at the Boulder Canyon site. After this dam is built, possibly the experiment of constructing a rock-fill dam at Lee Ferry may be undertaken, as suggested by the author. If this construction was undertaken when the Boulder Canyon Reservoir was purposely nearly empty, no great damage might occur if the Lee Ferry rock-fill dam should suffer a blow-out during construction.

The writer is particularly interested in the problems of the Colorado River for the reason that he believes he has solved in part what might be called the problem of the Lower Colorado River below Boulder Canyon. Up to the present time, it was believed by many engineers who investigated the lower course of the river, that it was not economically feasible to build a high dam across the river for power purposes. The reason for the negative result of these investigations lies probably in the fact that bed-rock, at the deepest point in the river channel, is more than 100 ft. below the present stream bed. Furthermore, the flow in the river is seldom less than 4 000 sec-ft., and floods of 150 000 to 200 000 sec-ft. may be expected almost every year.

About 5 miles above Parker, Ariz., the solid rock banks on both sides of the Colorado rise about 100 to 120 ft. above the river bed and are 600 to 700 ft. apart. Through the protruding rock hills on the Arizona side, it is proposed to cut a channel about 250 ft. wide, somewhat lower than the present river bed, and, by means of a coffer-dam, to divert the flow of the river during the construction of an earth and rock-fill dam across the main river channel. After the main dam has been completed to the crest and a spillway of 200 000 sec-ft. capacity is excavated at a favorable location on the California side of the river, the temporary diversion channel may be closed by a concrete arch dam, at the foot of which the power-house might be built. The main dam, which would

be about 100 ft. high, would be of the earth and rock-fill type with a concrete core-wall reaching to bed-rock or to a double row of sheet-piling to prevent percolation through the dam.

With a load factor of 70% and the quantity of stored water available between the sill of the spillway and the crest of the 15-ft. gates on top of the spillway, about 100 000 h. p. could be developed. The remainder of the reservoir is thereby assumed to be silted up. The intake to the turbines will be through the arch dam, thus affording a minimum cost of installation and a maximum degree of efficiency for operation. At the tail-race of the power plant, a part of the water discharged by the turbines may be taken in a canal and used for the irrigation of about 120 000 acres of land a short distance below the dam. Complete plans for the irrigation of this land were prepared some time ago by the U. S. Indian Service.

The temporary diversion channel would require the excavation of about 1 000 000 cu. yd. of rock, of which a part might be used in the construction of the main dam.

Thus, by the somewhat unusual method of diverting a mighty river into a new channel, then building, without any undue risks, a dam across the main channel, and closing afterward the temporary diversion canyon by a concrete arch dam, under the most favorable conditions as to rock foundation and side abutments, a safe and economical solution, in part, of the problem of the Lower Colorado River is effected.

It is of further interest to note that the proposed reservoir near Parker would afford an excellent opportunity for temporary flood control for Imperial Valley during the construction of the Boulder Canyon Dam. The time required for building the Boulder Canyon Dam may be 10 years, while the dam at Parker could be constructed within less than 2 years. The capacity of the Parker Reservoir is about 1 500 000 acre-ft., and the silt deposits from the river may reduce this capacity by about 100 000 acre-ft. per year. As the dam will be used later mainly for creating head for the power plant, the silting process of the reservoir is of minor importance.

KIRK BRYAN,* ESQ. (by letter).†—During the extensive surveys of the Colorado River by the U. S. Geological Survey in 1921, the writer was detailed to conduct geological work in the vicinity of Lees Ferry.‡ The results of this work, in so far as they affect the building of a dam at Lees Ferry, are presented herewith. The paper by Mr. La Rue has raised definite questions in the solution of which the geologic facts are pertinent.

Rocks Involved.—The rocks in the vicinity of Lees Ferry are sedimentary in character and form great beds of like material that are persistent in composition over large areas. The character of these rocks is shown in Table 2.

The distribution of these rocks is shown on the geologic map, Fig. 9, from which also the reader will be able to locate various features of the topography

* Geologist, U. S. Geological Survey.

† Received by the Secretary, June 9th, 1922. Published by permission of the Director of the U. S. Geological Survey.

‡ Spelled according to the ruling of the U. S. Geographic Board, December 1st, 1915, U. S. Geographic Board, 5th Rept., 1921, p. 190.

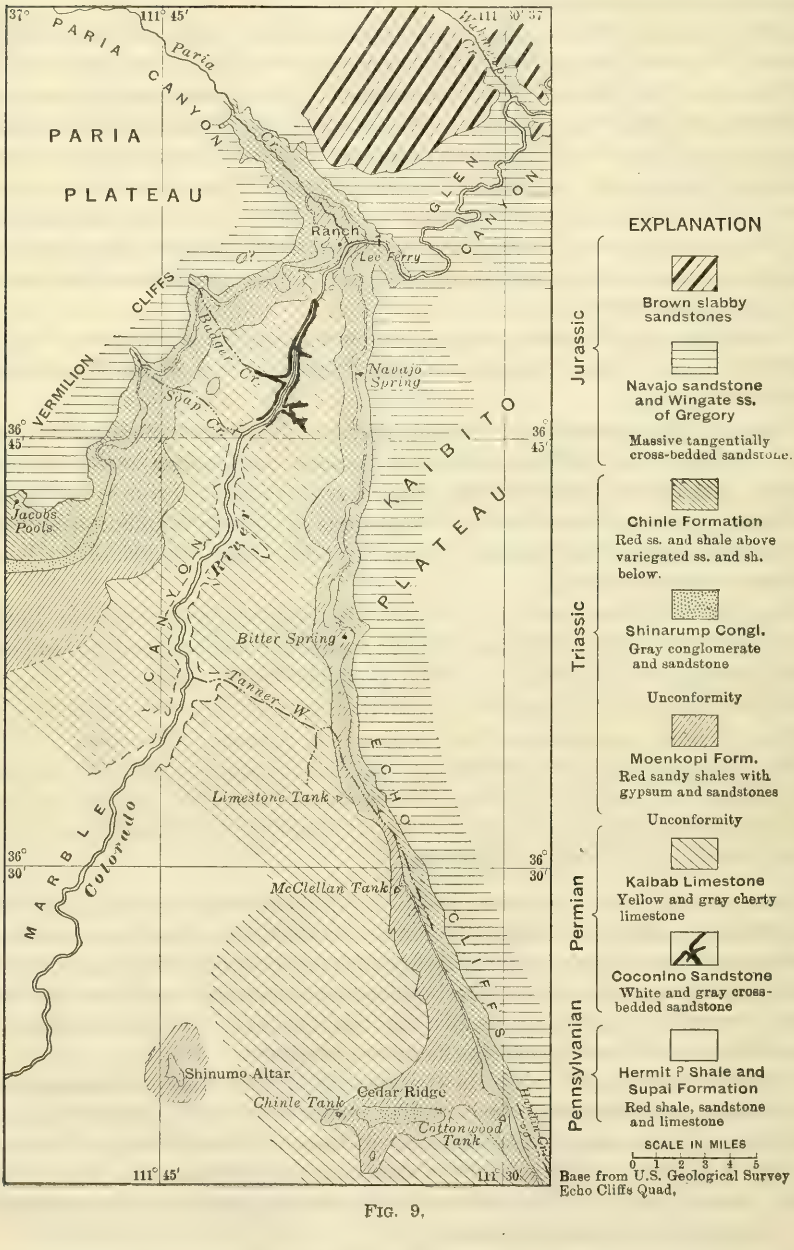

PARIA CANYON
Paria
PARIA
PLATEAU
Ranch
Lee Ferry
GLEN CANYON
VERMILION CLIFFS
Badger Cr.
Soap Cr.
Navajo Spring
KAIBITO PLATEAU
Jacobs Pools
CANYON
River
Bitter Spring
Tanner W.
Limestone Tank
ECHO CLIFFS
MARBLE
Colorado
McClellan Tank
Shinumo Altar
Cedar Ridge
Chinle Tank
Cottonwood Tank
EXPLANATION
Jurassic
Brown slabby sandstones
Navajo sandstone and Wingate ss. of Gregory
Massive tangentially cross-bedded sandstone.
Triassic
Chinle Formation
Red ss. and shale above variegated ss. and sh. below.
Shinarump Congl.
Gray conglomerate and sandstone
Unconformity
Moenkopi Form.
Red sandy shales with gypsum and sandstones
Unconformity
Permian
Kaibab Limestone
Yellow and gray cherty limestone
Coconino Sandstone
White and gray cross-bedded sandstone
Pennsylvanian
Hermit ? Shale and Supai Formation
Red shale, sandstone and limestone
SCALE IN MILES
0 1 2 3 4 5
Base from U.S. Geological Survey Echo Cliffs Quad.

FIG. 9.

FIG. 10.—VIEW DOWN MARBLE CANYON, FROM NEAR LEES FERRY, SHOWING THE VERMILION CLIFFS AND TOPOGRAPHIC EXPRESSION OF FORMATIONS DISCUSSED IN TEXT.

which are discussed subsequently. Fig. 10 shows the formations from the Kaibab limestone to the top of the Jurassic sandstone with the characteristic topography of each formation.

TABLE 2.

	General Section of Rocks near Lees Ferry.	Feet.
Jurassic......	Brown thin bedded sandstones and shales.	?
	(Wingate and Navajo of Gregory). Massive tangentially cross-bedded red to buff sandstones. No parting visible at the center, but upper half has lenses of dense gray limestone 6 in. to 3 ft. thick at intervals and near the top, nodules of limonite the size of peas are common. In the Vermilion Cliffs the upper half is distinctly lighter in color.	1 100-1 200
Triassic.......	Chinle formation (Upper Triassic). Blue, green, and red shales; white, gray, purple, and red sandstones; and cherty limestones. Upper part of Chinle formation consists of heavy bedded sandstones and red shales. Lower part contains fossil wood.	1 000±
	Shinarump conglomerate (Upper Triassic?). Gray conglomerate with lenses of sandstone and shale; much fossil wood.	0-40
	Unconformity.	
	Moenkopi formation (Lower Triassic). Red sandy shales and thin bedded sandstones with seams of gypsum. In places has beds of red and gray sandstone 2 to 6 ft. thick, and in one locality 12 ft. of gypsiferous limestone. Base, generally, 1 to 10 ft. of chert conglomerate.	500±
	Unconformity.	
Permian......	Kaibab limestone. Yellow limestone with numerous more or less rounded nodules of chert.	250
	Coconino sandstone. Gray cross-bedded massive sandstone.	300
	Unconformity (?)	
	Hermit (?) shale. Red shale and sandstone.	
	Unconformity (?). (Not observed).	
Permian (?) and Pennsylvanian........	Supai formation. Red shale with beds of blue limestone.	500+ observed

Of these formations, the sandstones of the Jurassic Age form high and conspicuous cliffs in Echo Cliffs, Vermilion Cliffs, and Glen Canyon. In many places also, the almost sheer cliff is continued downward in the ledges of red sandstone and intervening shales of the upper part of the Chinle formation. In general, however, the Chinle formation forms ragged badlands or is concealed below the débris from the overlying cliffs. The Shinarump conglomerate commonly forms a cliff and sustains a platform which lies like a fret at the base of the walls of the overlying formation. In places, however, this conglomerate is thin or wanting and the badlands of the Chinle formation merge into the topography of the underlying Moenkopi. The red sandy shale and thin sandstones of the Moenkopi formation usually stand as corrugated cliffs under the protection of the Shinarump. The resistant and Cherty Kaibab limestone forms the top of the extensive plateaus that bound the Marble Canyon of Colorado River southwest of Lees Ferry. Within Marble Canyon, the Kalibab forms a succession of cliffs and often a sheer cliff down to the Coconino sandstone, which is in turn a persistent cliff maker. The Hermit (?) shale and Supai formation together form a series of cliffs and talus slopes down to the great cliff to the Redwall limestone which is not exposed within the area.

General Structure.—The rocks which have been described in the preceding section are affected by two structures which are of importance in the distribution of the rocks and also affect the problem of constructing a dam at Lees Ferry. The Echo monocline extends from the Painted Desert about 50 miles south of Lees Ferry through Lees Ferry and dies out to the north. Along this structure, the beds have a dip to the east of about 10° over a zone from 1 to 5 miles wide. East and west of this zone the beds lie horizontal or nearly so. In consequence of this monoclinal fold, each bed stands from 1 000 to

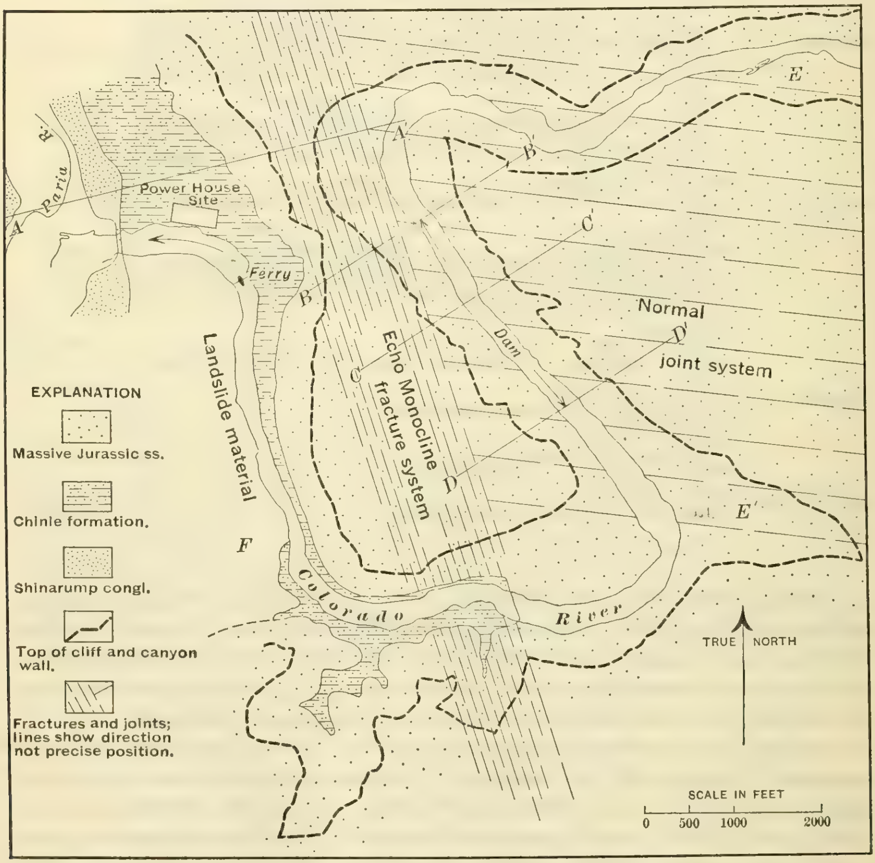


Fig. 11.

2 000 ft. higher in the area west of the monocline than in the area on the east. Erosion has proceeded in such a manner as to strip from the area west of the Echo monocline most of the formations down to the Kaibab limestone. The Echo Cliffs mark the zone where the folding is most intense. The second structure of importance is the general or regional northerly dip. In consequence of this structure the Echo Cliffs and Echo monocline fade out to the north. The inclination of the beds due to this structure is from 1 to 2° and is more noticeable west of the Echo monocline than east of it. Erosion

has stripped all the formations to the top of the Kaibab limestone as far north as the base of the Vermilion Cliffs. Lees Ferry lies in the angle between the Echo Cliffs and the Vermilion Cliffs. At the Ferry, the beds are dipping about 10° eastward. East of the Ferry, they are horizontal or nearly so. West of Lees Ferry at the base of Vermilion Cliffs they dip about 1° to the north.

Character of the Rocks at the Dam Site.—Lees Ferry dam site, as recommended by Mr. La Rue, lies in the first bend of the river up stream from Lees Ferry. In Fig. 11 the distribution of the rocks is shown on a larger scale. The map is redrawn from the topographic map made by the U. S. Geological Survey in 1921. The straight reach of the river in which the dam site is to be located is carved in the massive Jurassic sandstone. The only available site for the power plant is, however, west of the ferry in an area underlain by the Chinle formation. The Echo monocline crosses the area at about the center line of the first loop of the river. West of the lines showing the Echo monocline fracture system in Fig. 11, the rocks dip about 10° to the east. East of these lines they appear to be horizontal or nearly so. Construction then, as far as the dam itself is concerned, has to deal only with the massive Jurassic sandstone. This sandstone is unusually massive, having few joints and relatively few bedding planes. Almost all the sand grains are of quartz, imperfectly rounded, but without sharp edges. According to Gregory,* the Navajo sandstone or upper member of the Jurassic standstone as here treated, consists of sand grains of two sizes. Grains 0.15 to 0.25 mm. make up 90% of the rock, other grains, averaging 0.65 mm. in diameter, form an interrupted coat on the cross-bedding laminæ. The sandstone is somewhat loosely cemented with calcium carbonate. In addition to the lime cement, the sandstone contains iron oxides which give it a red or buff color and in places, especially near the top of the formation, these oxides are concentrated in nodules or concretions about the size of peas. In places in the Navajo country, the cement is siliceous. At intervals through the sandstone are beds of limestone from 6 to 18 in. in thickness, and these beds fade out laterally in short distances. The limestone is gray and crystalline and, as far as known, unfossiliferous. The most striking characteristic of the massive sandstone is its cross-bedded character. The cross-laminæ are from $\frac{1}{8}$ to $\frac{1}{2}$ in. thick and consist of sand grains of two sizes, the finer grains which make up the bulk of each lamina being separated from the next lamina by a layer of larger grains. These cross-laminations extend across the face of the rock in groups of great curved lines that are generally tangent to the curve of lower groups or to the bedding planes. The cross-lamination is on a grand scale, sweeping curves being from 10 to 200 ft, or more, in length. The sandstone in places has a tendency to split parallel to these cross-laminæ. In other places, the rock is so uniform in strength that erosion produces rounded forms. In addition to the features just described, the sandstone is cut by vertical joints the strongest of which strike in a generally northwest direction. These joints divide the rock into great plates along which erosion is most effective. In Fig. 4† of the author's paper, these joints may be seen on the left hand or east side of the dam site. The spacing of the joints is

* Gregory, H. E., "Geology of the Navajo Country", U. S. Geological Survey, *Professional Paper 93*, 1917, p. 58.

† *Proceedings*, Am. Soc. C. E., April, 1922, p. 841.

of the greatest importance. In some places they are from 20 to 50 ft. apart and the walls are very sheer and straight. At other places, for a distance of 100 to 200 ft., the joints are close together, being from 1 to 10 ft. apart. At these places the walls are irregular and are cut back by narrow, steep-sided gulches and side canyons. In Fig. 11 the general direction of these joints is shown diagrammatically and the parallelism of the minor canyons with the joint system is brought out. Folding along the Echo monocline impressed on the rocks is another system of vertical joints that has a northerly trend. In Fig. 4 of the author's paper, the rocks of the right foreground have a schistose appearance which is due to this north-south system of joints. In Fig. 11 this belt of joints is shown diagrammatically. These joints are in the nature of fault fractures due to the elevation of the western part of the region with respect to the eastern. In places the fractures are close together and in other places widely spaced; they branch, fork, and interlace. Some of them are small faults. These joints are filled by crystalline calcium carbonate and iron and manganese oxides.

The rocks of the dam site are essentially uniform in character from the water level to the top of the cliffs. The advantages and disadvantages are thus equal for any height of dam which may be constructed. The crushing strength of the rock is low, but the fact that it stands in great walls in a state of nature indicates that its crushing strength is ample for a high structure. However, in a rock-fill dam, as is proposed, some of the blocks will be forced to bear very heavy loads while resting on a point rather than a flat surface. Such rocks will undoubtedly be crushed, and Mr. La Rue is correct in assuming that there will be a large amount of adjustment to load in a rock-fill dam composed of this material. This crushing and adjustment, however, will tend to compact the structure. The presence of streams of water when such adjustment is taking place, will doubtless carry away the fine débris and tend to prevent the closing of cavities.

According to Mr. La Rue's proposition, it is expected to blast down the material from the cliffs to form the dam. The rock, however, is so unusual a type that a number of problems will arise in this connection. The writer with the assistance of Mr. Frank Mitchell made one test shot. A small amount of blasting was also done in the installation of a cable for stream gauging. This limited experience indicates that the massive but porous sandstone presents special problems in blasting. The quantity of powder necessary and the best type of holes or galleries for loading this powder will have to be determined experimentally. It should also be pointed out that the east side of the dam site is affected by vertical joints which strike diagonally to the cliff face. These joints will have a large but unpredictable effect on the blasting. The west face of the dam site from the center line south is similar to the east side, but from the center line north the rock is affected by the north-south system of joints referred to previously. The blasting in this locality may be no more difficult than in other places, but the action will be somewhat different and probably the chunks obtained will be smaller. It seems therefore necessary to recommend that preliminary work be done on a rather large scale to determine what the exact conditions of blasting will be, before the first

great blast by which Mr. La Rue proposes to raise the dam 250 ft. above river level. When these experiments are conducted it will be possible to obtain data on two important questions. One of these is the size of blocks which can be obtained by blasting and the other is the quantity of fine material which will be produced. It seems obvious that it will be necessary to have very large blocks on the down-stream side of this proposed dam during the period when it is not yet water-tight. An unknown quantity of fine material will be produced during blasting and by the fall of blocks. In Nature, very large blocks can fall the full distance from the top of the cliffs to the bottom without breaking, but the fact that such blocks are found does not indicate how many similar blocks have been crushed by this same fall.

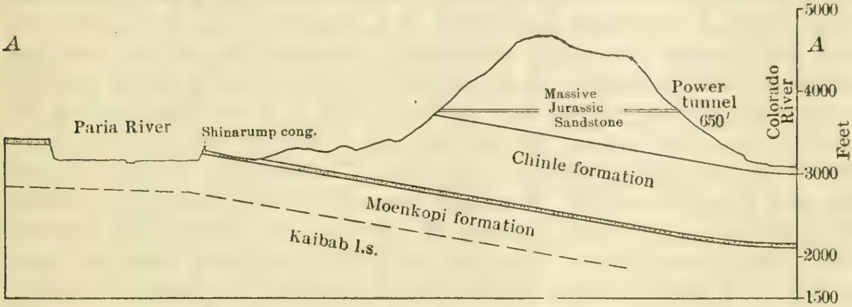


FIG. 12.

Location of Tunnels.—Dependent on the detailed plans which may be adopted, tunnels may need to be driven in the line of *E E′* and *A A′* as shown in Fig. 11. Tunnels along the line, *E E′*, either for diversion of the river during construction or as a permanent wasteway after construction will be driven through the massive Jurassic sandstone entirely. Large tunnels can be constructed at a minimum of expense because of the ease of drilling the rock and because its massive character will require no support for the roof. However, unless the velocities in the tunnel are low, a concrete lining will be necessary to prevent wear. It seems likely also that there will be losses to the adjacent porous sandstone if the water in the tunnel is under great pressure and that this water percolating through the sandstone may eventually find or work out channels large enough to produce serious losses from the tunnel and direct the water toward inconvenient places. At Locality *A A′* a tunnel may be required at a low elevation or at a high elevation to act as a spillway. A tunnel or tunnels to carry water to the power-house will certainly be built here because the flat, east of the present ferry, is the best if not the only available power-house site. The geologic section, Fig. 12, shows the character of rock which will be encountered in tunnels at various elevations. The folding along the monocline brings up the lower formations to river level and above on the west flank of the ridge. Tunnels at low elevations will pass from the massive Jurassic sandstone on the east into the red sandstones and shales of the upper part of the Chinle formation and thence into the cherty limestone and soft shales of the middle of this formation. Tunnel construction in the middle of the Chinle formation will require thorough support for the roof and a permanent concrete

lining. The red sandstones and shale of the upper part of the formation will probably present no difficulties during construction, but a lining will be required as in the Jurassic sandstone. The location of tunnels at the lower elevation becomes then an engineering problem as to relative cost of a short tunnel at Locality *A A′* or a longer tunnel at Locality *E E.′* Tunnels at Locality *A A′* and at an elevation of 650 ft. will be required for carrying water to the power plant. These tunnels will be wholly within the Jurassic sandstone and require no comment either on their construction or location.

Leakage.—On the assumption that the water-tight dam to an elevation of 720 ft. is constructed in the straight stretch of river east of Lees Ferry, consideration was given to the problem of leakage. The west wall of the reservoir is relatively narrow, but the massive Jurassic sandstone is cut by numerous sealed joints, as mentioned previously. It is considered that these joints will form fairly perfect obstacles to percolation. Similarly, the folding which has carried the Chinle formation up to elevations of about 3 500 ft. on the west side of the ridge near the present ferry has laid a dam of rather tight rocks in the path of percolating waters. On the east side of the dam the reservoir wall is formed by the massive Jurassic sandstone. The minimum distance through this wall is about 6 000 ft. A certain amount of direct percolation through the pores of the rock may be expected. Most of the leakage will, however, occur along vertical joints. However, the direction of these joints, as shown on Fig. 11, is nearly at right angles to the direction of this flow. If considerable leakage should take place through the sandstone and large springs break out below the toe of the dam and in the canyon at Locality *E′*, it seems unlikely that such leaks would affect the stability of the canyon wall.

Depth of the River Channel.—The depth of the water during mean high water at the gauging station above Lees Ferry ranges from 13 to 17 ft. The bed of the river is composed largely of sand. Near the margin of the channel are numerous large rocks which have fallen from the cliffs. Many of these seem to be relatively stable in position and not easily dislodged by floods.

It is practically impossible to predict the distance to bed-rock in such a channel. If the river has cut its bed normally, the thickness of gravel and sand will be only that of scour and fill during great floods. Such scour and fill should be relatively moderate in amount, but is an unpredictable quantity. The Shinarump conglomerate crosses the river channel west of the ferry (see Fig. 11). Mr. La Rue believes that bed-rock extends across the channel at this point at low water. If this ledge exists, then there has been no general silting of the channel. At the dam site there may be, however, a hole or deep in the rock bed of the river due to the presence of a fossil plunge-pool. A plunge-pool or over-deepening of the stream bed occurs at all falls and it seems possible, although there is no direct evidence, that the Glen Canyon of Colorado River was cut back as a head-water falls from the line of Echo Cliffs eastward. As the falls receded, successive plunge-pools would be filled with gravel to bring the river to a uniform grade. It seems necessary for the determination of the depth to bed-rock to proceed in the usual manner by drilling.

Observations on the Scheme for a Rock-Fill Dam.—Mr. La Rue's scheme for a rock-fill dam, which is to be made water-tight by sluicing in a fine

material during construction, is a bold solution of the problem for a dam at Lees Ferry. The difficulty of obtaining suitable material as well as the isolation of the locality required such a solution, and the author is to be complimented on his originality and vision. In advance of building such a dam it may be assumed that the thickness and character of the sand and gravel above bed-rock will have been determined and that experiments will have been conducted to determine the best method of blasting the massive sandstone walls.

Fine material for filling the interstices of the dam can, according to Mr. La Rue, be found up stream at various sand-bars and banks. A roadway up the canyon is impracticable and the navigation of the canyon is attended with some difficulties, even with the assumption that preliminary blasting will raise the water level and pond the water for a distance of 15 or 20 miles. Another source of fine material was therefore sought. The Moenkopi formation consists largely of sandy shale and might make suitable material for filling such a dam except for its rather high content of gypsum and other soluble salts. Continual solution of this material would make it an ineffective filler for small spaces. Similarly, the base of the Chinle formation, consisting of gray, green, and blue shales, is suitable in that it is clayey, particularly where it is weathered. but this formation also contains a considerable quantity of soluble material. Systematic sampling and some simple laboratory work might show that these clays could be used. The upper part of the Chinle formation consists of heavy, bedded, earthy sandstone and sandy shales, and this part of the formation appears to be rather free from salts, but it is so exposed in cliffs that it can not be easily quarried. It therefore occurred to the writer that the heterogeneous landslide material on the south bank of Colorado River opposite the ferry in the general locality marked *F* in Fig. 11, might be a suitable source for part of this material. The material has been in position for some time and the soluble matter has doubtless been leached out. There is also a large sand dune which is free of soluble matter. By installing a crusher and mixer, the surface of this slump or landslide area and the dune could be stripped with steam shovels and crushed, obtaining as a result a mixture of disintegrated shale and leached sandstone which would have a texture similar to loam. Loaded into cars this material could be brought across the river and carried to the top of the bluff on an inclined railway. The use of this material depends on its relative cost.

It seems probable that in blasting the cliffs a large quantity of fine material would be obtained which, unless precautions are taken, is likely to be lost. If as a preliminary to the large blast, which is to raise the dam to 250 ft., a small low dam is thrown across the river at or slightly below the toe, the dam would then be built in slack water and much more fine material would be saved.

Mr. La Rue's scheme is generalized, and he has assumed that blasting in the cliffs would produce a relatively even crest line at any given point on the dam, but it should be borne in mind that the material will slide into the dam site in the manner of a series of talus cones and the low point of the dam at any cross-section will be near the center line of the river. The difficulties may be visualized by a consideration of the cross-sections shown in Fig. 13. Line *C C′* is at

the center of the dam as proposed by Mr. La Rue, and the other lines at the uper and lower points, respectively. In Cross-section C C' a 1 on 2 slope has been projected. It is possible that the material when blasted will slide into the lower part of the canyon on this slope, but it is unlikely that the heap of loose material will stand on this slope. It seems more likely that it will assume a

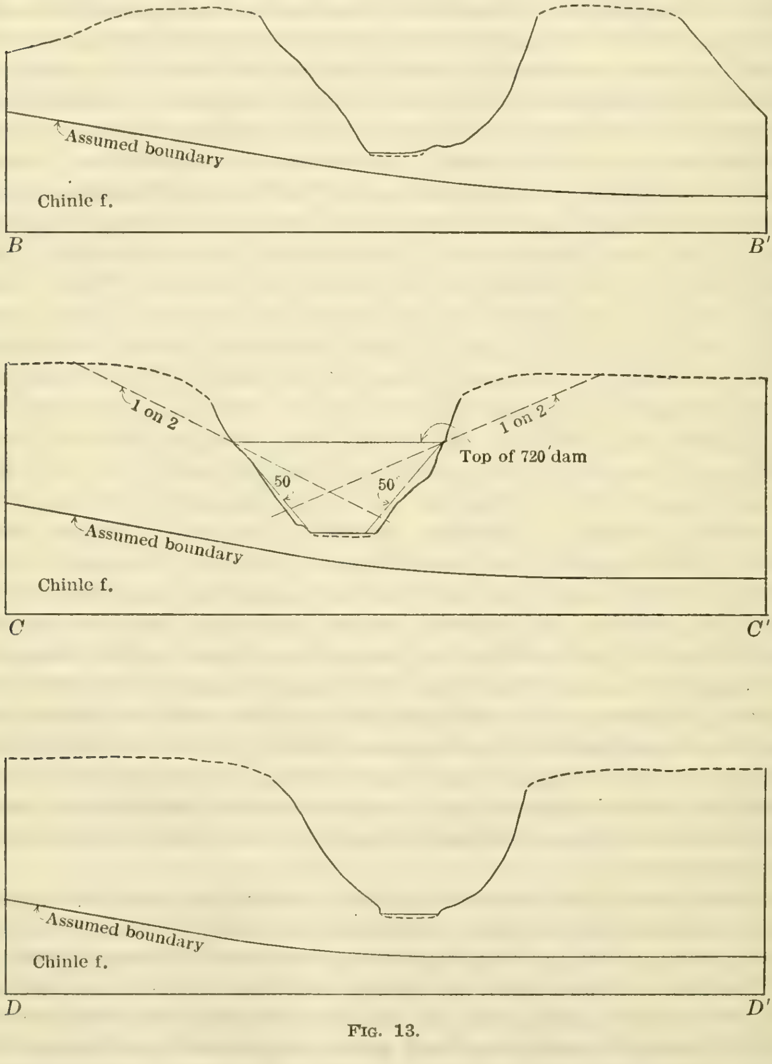


FIG. 13.

slope between 35 and 50 degrees. The existing talus which occurs at intervals along the canyon walls doubtless has the minimum slope. Three talus cones shown on the large topographic map of the dam site have maximum slopes between 29° 30′ and 33° 30′. The artificial cones will be less stable and will probably have coarser material. Overtopping of the dam during construction is a

serious matter if the water will be concentrated in a V-shaped trough near the center line of the dam, because the maximum velocities will thereby be obtained. It may, therefore, be necessary to hand-place a considerable part of the material near the longitudinal center line of the dam, or blast in an excess of material so that the center line will be the required height.

Materials for Construction.—The local materials available for general construction purposes are considered in the following paragraphs.

The Coconino sandstone, Hermit (?) shale, and Supai formation are exposed only in the Marble Canyon or its tributary canyons. The outcrops are so inaccessible that these formations may be dismissed as sources of material.

The Kaibab limestone is exposed over large areas southwest of Lees Ferry, and there are numerous places where quarrying can be done economically. The formation is about 250 ft. thick and consists almost exclusively of yellow limestone with nodules of chert. No beds were seen which gave any promise of being valuable for making cement. Dimension stone of large or small size can be readily obtained. The hard chert nodules are so numerous that the cost of facing blocks with a chisel or hammer will be large. The rock can be considered as available only for rough ashlar or rubble masonry. It would, however, make excellent crushed rock for concrete or macadam.

The Moenkopi formation is a sandy shale with interbedded thin sandstones and contains considerable gypsum. It is valueless for structural purposes.

The Shinarump conglomerate is about 40 ft. thick and forms a gray ledge above the "dug way" and the ridge on the east side of Paria Creek. It is a cross-bedded conglomerate of well-rounded silicious pebbles with lenses of sandstone and small lenses of green shale. Fragments of fossil wood and logs of trees are abundant. This conglomerate is hard and durable, has widely spaced vertical joints, and is an excellent rock for rubble or Cyclopean masonry. It is somewhat too hard and coarse-grained to be easily worked into blocks of uniform dimension.

The Chinle formation is a very complex unit consisting of gray, green, and blue shale below, white and purplish sandstone and shales, cherty limestone and shales in the middle part, and in the upper part massive red sandstones and shales. Only the upper part contains material of any value for construction purposes. The red sandstones have a pleasant color, can be obtained in large and small sizes, and are easily worked. They have no great crushing strength, nor are they suitable for masonry which is to be alternately wet and dry. The best site for a quarry to obtain these sandstones which might be used for the construction of the power-house is on the high point south of the present ferry, where these sandstones dip 10° to the east. Small quantities of such stone can, however, be obtained near the power-house site from the adjacent ledges and the rocks of the talus.

The characteristics of the massive Jurassic sandstone have already been discussed. Except for the rock-fill of the dam, this rock is not suitable for construction purposes.

Large quantities of sand and gravel can be obtained from the bar at the mouth of Paria River about a mile west of the ferry.

ARTHUR P. DAVIS,* PAST-PRESIDENT, AM. SOC. C. E. (by letter).†—The first proposition known to the writer for constructing a high dam in a large stream on an alluvial bottom by dumping loose rock into the flowing water without diverting the river or excavating the foundation was made by the late A. G. Menocal, M. Am. Soc. C. E., Chief Engineer of the Maritime Canal Company, who proposed such an operation for a dam about 65 ft. in height on the San Juan River, a few miles below the mouth of the San Carlos at a point called Ochoa, where the river forms the boundary line between Costa Rica and Nicaragua. The following extract from a paper‡ prepared by Mr. Menocal for the Water Commerce Congress at Chicago in 1893 describes the dam and method of construction:

"It consists in dumping from an aerial suspension conveyor large and small material properly assorted, across the river from bank to bank until a barrier is created sufficiently high and strong to arrest the flow and hold the waters at the required level, the body of the dam to be made up of large blocks of stone, weighing from 1 to 10 tons, and smaller material to fill the voids. Its base will be quite broad as compared with the height, probably from 400 to 500 feet between the foot of the upstream slope and the end of the apron. The top is estimated 30 feet wide, the rock upstream slope 1 to 1, and the apron, or downstream slope, 4 to 1, with the lower portion flattening down to 5 or 6 to 1. On the upstream side small material, such as stone, fragments of gravel, clay, etc., selected as circumstances may require, will be deposited as the work advances, in sufficient quantity, as tight as wanted. It is not expected or even desirable to have a water-tight structure, the object sought being simply to oppose such an obstruction to the river as may be necessary to hold the waters at the required level. The minimum flow of the river is about ten times the water needed for working the canal. Consequently, nine-tenths of it can be wasted with advantage. That the dam will eventually become tight there can be no doubt, as the small drifts and detritus forced in by the current will gradually fill the voids and consolidate the structure.

"The method of construction will be quite simple. After protecting the abutments against possible erosion, large pieces of rock will be dumped in the bed of the stream from three or four cableways spanning the valley. The material should be distributed uniformly over the area under the main portion of the dam, commencing up stream and keeping up, as nearly as possible, an even level. Scouring will soon cause settling of the blocks into firmer soil, the upper level in the meantime being constantly raised by depositing more stone, while the small material is being forced by the current into the voids, and the overflow dislodging and rearranging the unstable blocks until they reach a final resting place. This process to be continued until the resistance at the bottom becomes so great as to check scouring due to maximum pressure, when the dam will be carried up to the desired level. The river, in the meantime running over the mound, will readjust the material in and adapt the apron to the necessary conditions of stability to withstand the effect of the fall, and carry off the water safely. If the dam is then raised so as to shut off a whole or the largest part of the river flow, which can by that time be discharged over the waste weirs, the structure will be permanent."

It was proposed that this dam be an overflow weir, and this feature has been generally condemned.

* Director, U. S. Reclamation Service, Washington, D. C.

† Received by the Secretary, June 16th, 1922.

‡ H. R. Document No. 279, 54th Cong., 1st Session, p. 53.

The Nicaragua Canal Board, consisting of the late William Ludlow, M. Am. Soc. C. E., Mordecai T. Endicott, Past-President, Am. Soc. C. E., and the late Alfred Noble, Past-President, Am. Soc. C. E., studied the plans of the company and made the following comments* on this design:

"It appears from this account of typical existing dams that, although rock-fill dams are not new, and although weirs have been built on sand and maintained successfully, the Ochoa Dam is actually without precedent in its more serious aspects, and its construction will be far more difficult than any that have been mentioned. The successful rock-fill dams have impervious foundations, and are made water-tight by sheathing or masonry. The materials in them are in great part hand laid, adding greatly to their stability, and none of them has been built in conflict with the forces of a great river or was intended to be used as a weir for the discharge of floods.

"As to this last point, the Board is clear in its judgment that no such endeavor should be made in the case of the Ochoa Dam, as involving an unwarrantable hazard to the safety of the structure and of the canal navigation."

* * * * * * * *

"The weakest point of a dam built as the company proposes would probably be at the river bank, where the loose rock will meet the steep clay slope. The method proposed for protecting this point by lines of sheet piling and concrete core seems entirely inadequate. A better construction would involve the use of a caisson on each side of the river, located so as to be partly in the river channel and partly in the firm clay bank, and sunk by the pneumatic process to bed rock if within reach by that means, or if not at least below reach of scour. It seems probable that either bed rock or a mass of boulders would be found near sea level, elevation 0. The caisson should be surmounted by a concrete wall, extending up the hillside beyond the caisson to the highest elevation to be reached by the water surface after the completion of the dam, say 114 or 116. A trench 20 feet or so in depth, or deeper if necessary to reach firm material, should be excavated in the hillside for the core wall. This work done, the river banks and hillsides below high-water level should be covered with a heavy mass of large stones and an additional amount held in reserve before depositing any rock in the river. The result of this would be to contract somewhat the width of the river channel, which would at once scour out so as to maintain its normal cross section. A considerable scour would be desirable, because it is important that the rock mass be sunk deeply into the river bed, since, if rock or a bed of boulders or heavy gravel can be reached, the safety of the structure will be increased greatly. In depositing rock in the river those methods should be used which will induce scour, and possibly the building out from each side may best answer this purpose."

* * * * * * * *

"The rock mound would be quite permeable, and the water pressure against it would vary with the volume of the discharge. To make it hold water, an embankment, which would form the real dam, the rock mound serving as its support, must be built on the upstream side. It is proposed to make the embankment of fine stone, gravel, clay, etc., with the view that a quantity of these materials should be carried well into the rock mound. An embankment composed largely of clay dumped in the water would take a much flatter slope than 3 : 1. For these reasons the quantity estimated by the company would have to be increased largely, and means may have to be adopted, not contemplated by the company, to render the dam tight enough to answer its purpose, as the permissible leakage is much less than the company has assumed.

"By the addition of the embankment, and the retardation by friction of the flow of water through the underlying sand bed, the dam will be rendered more

* H. R. Document No. 279, 54th Cong., 1st Session, pp. 61–64.

secure from undercutting and consequent settlement; but some doubt as to ultimate security will still remain. Confidence would be gained to a certain extent during the construction of the dam, if no breaches were caused by the annual floods, but it would require a considerable period of time after the completion of the dam to allay all apprehension. If a site can be found where the dam can be built above a rock or other stable foundation, the permanence of the structure will be rendered much more probable and the uncertainties of construction reduced.

"If such a dam becomes breached with the great volume of water standing at a high level against it, destruction would follow quickly. The crest, therefore, should be raised so far above the surface of the water in the pool that a considerable settlement could be sustained without sinking the crest below the water surface."

It should be noted that the Board places emphasis on the importance of scour in settling the foundation as far into the sand as possible. It is also to be noted that this eminent board of engineers was doubtful of the permanent safety of a dam even of this height under these conditions.

The practical application of the method of damming a large river by dumping rock on a bed of silt while the river flowed over it was made by the Southern Pacific Company in 1906, in the spectacular control of the Colorado River when it was flowing into Salton Basin. The same method was used in constructing a coffer-dam across the Colorado River in making the final closure for the Laguna Dam. In neither case, however, was the water allowed to flow permanently over the rock-fill as proposed by Mr. Menocal, and the rock used was settled deep into the silt by the erosion of the water during construction.

The author proposes no means for effecting a water-tight junction between the rock-fill and its abutments, and the writer sees no effective method of accomplishing such a junction between the proposed silt filling and the rock. Under such a head, water would follow the rock with a velocity likely to become erosive at many points, and thus open avenues of danger. The best solution seems to be a concrete pavement cemented to the abutments with all the care and precaution that the highest skill can suggest. Cracks which might appear should be sealed with a cement gun on the first opportunity.

In considering the construction of a loose rock dam in Boulder Canyon during the past few years the Government engineers and those whom they have consulted have regarded the settlement of the loose rock into the soft material as deeply as possible as one of the most important and difficult operations to accomplish, and it seems obvious that it cannot be made perfect without excavating the loose material, but might perhaps with many precautions be made to sufficient extent to secure safety.

The author's proposal to deposit enough rock in the river at one blast to bring the dam to the 250-ft. level seems especially designed to prevent any water action in the direction of scour and of sinking the rock into the silt. He says:

"If the canyon walls were blasted into the river, the heavy mass of material would settle to the level of the boulders, assumed to be 60 ft. below the bed of the river, and some of the fine sand and silt would be forced up."

No reason is given for this important conclusion and the methods proposed seem likely to prevent this desirable result.

If this dam were built by the methods suggested by the author, there would be a considerable part of the structure below the river bed founded upon sand and silt. As the water rose in the reservoir after the dam was completed, the head on this silt would gradually increase and no assurance could be given that a critical point might not be reached when the reservoir is nearly full, and sufficient percolation through the foundation might take place to start erosion and cut a channel through the silt. A free channel ever so small, resulting from the slight arching of the rock, which would conduct water through the sand at a velocity due to more than 700 ft. of head, would scour rapidly, carrying considerable rock until a channel was excavated large enough to allow the rock above to settle, and unless this was accomplished in one motion the scour would continue until the main rock-fill fell into place. If it was arched sufficiently it would not do so promptly, and the scour would continue until the opening would carry a flood much larger than normal and do great damage below. It seems inevitable, however, that eventually the rock-fill would fall in place and stop this. If, in so doing, it should fall below the level of the water in the reservoir, the dam would be overtopped. No loose rock dam has ever been overtopped without failing, and some have failed. None of them has had a 780-ft. head nor 50 000 000 acre-ft. of stored water behind it to complete its destruction.

It should be remembered that the proposed reservoir of 50 000 000 acre-ft. has an area of 235 000 acres, and a discharge of 1 000 000 acre-ft. would lower the reservoir only about 6 ft. This would afford an average flow of 500 000 sec-ft. for 24 hours. No one can doubt that this would destroy the dam faster than it would lower the reservoir. The writer will not attempt to describe the results of suddenly releasing 50 000 000 acre-ft. of water. It would at least submerge and destroy the great Imperial Valley, and all improvements along the Lower Colorado River, and doubtless many lives would be lost.

It is readily seen that the danger of failure and the magnitude of the disaster are both greatly augmented with the height of the dam. This law applies especially to an unprecedented or doubtful design.

Where the necessary structure so far exceeds precedent, to build it any higher than needed would be inexcusable. The author appears to consider a capacity of 20 000 000 acre-ft. to be sufficient to regulate the river. The writer agrees with this estimate, but would provide 20% more to store silt and prolong the usefulness of the reservoir. There can therefore be no reason for building a reservoir of greater capacity than about 24 000 000 acre-ft., except for the increased head for power development. This site is so remote from markets and so much farther than many other available sites that there is at present no excuse, and for many years or decades there will be no justification, for developing power at this point. The available head can be utilized by building dams of moderate dimensions at other points without such unprecedented and hazardous characteristics.

The author states* that the construction of a dam near Lee Ferry would remove the menace from floods on the lower river, except floods

* *Proceedings*, Am. Soc. C. E., April, 1922, p. 845.

from the Gila River. That statement is erroneous, as the proposed dam would leave about 50 000 sq. miles of drainage area unregulated, besides that of the Gila. It is perfectly proper, as the author does, to except the Gila River, which for brief periods sometimes furnishes floods as great as those of the Colorado; but the area of 50 000 sq. miles between the mouth of the Gila and Lee Ferry should also be excepted. Most of this area can be intercepted by a dam at Boulder Canyon, which is the lowest point in the basin where this can be done, and is accordingly the proper place for storage purposes if the floods are to be controlled.

The author's Table 1 shows a capacity for Lee Ferry Dam of 50 000 000 acre-ft. and Boulder Canyon Dam of 31 680 000 acre-ft. The results of the actual surveys were probably not available to the author when he submitted his paper. These surveys have been in progress for a long time, and the results are now available and are shown roughly in Table 3 which gives the comparative area and capacity for each given height of the dam, as high as the surveys have been carried at Boulder Canyon.

TABLE 3.

Height of dam above river bed, in feet.	Boulder Canyon Reservoir.		Glen Canyon Reservoir.	
	Area, in acres.	Capacity, in acre-feet.	Area, in acres.	Capacity, in acre-feet.
50	3 500	88 000	4 000	100 000
100	7 500	362 000	7 000	375 000
150	15 500	937 000	10 800	820 000
200	25 000	1 950 000	16 600	1 505 000
250	33 500	3 413 000	24 000	2 520 000
300	44 000	5 350 000	34 000	3 970 000
350	57 000	7 875 000	47 000	5 995 000
400	73 000	11 125 000	63 000	8 745 000
450	90 000	15 200 000	85 000	12 445 000
500	109 000	20 175 000	114 000	17 420 000
550	132 000	26 200 000	145 000	23 895 000
600	157 000	33 425 000	178 000	31 970 000

Table 3 shows that, for the heights given, the Glen Canyon Reservoir would have less capacity than Boulder Canyon.

A dam 780 ft. in height in Glen Canyon near Lee Ferry would introduce not only unnecessary hazards, but would waste a large quantity of water by evaporation. A reservoir of 24 000 000 acre-ft. capacity in Glen Canyon, would have an area of about 125 000 acres, according to the available surveys, whereas one of 50 000 000 acre-ft. capacity would have a surface area of 235 000 acres and unnecessarily expose to evaporation 110 000 acres. This would be at its highest stages during the hot months of June, July, August, and September. Assuming an average excess area of 100 000 acres, and an annual evaporation of 6 ft. from the extra area, 600 000 acre-ft. of water would be wasted annually, all of which would be lost for use at the numerous high dams eventually to be built in the canyon below.

The utter absence of anything approaching a precedent to the proposed plans leaves the writer in much the same doubts as those which remained in the minds of the Nicaragua Canal Board previously quoted, and there apparently is sufficient doubt so that it would be inexcusable to attempt such a structure

where more conservative designs are possible or to build the dam under these conditions any higher than necessary.

Opinions concerning the safety of the proposed design can hardly be considered of much value until something is known of the underground conditions, which have not been investigated at Glen Canyon. Still less is it possible, under these conditions, to make intelligent estimates of cost of any type of dam. These conditions at Boulder Canyon have been carefully investigated, and comparative estimates of high concrete and rock-fill dams have been made by men with large experience in the construction of high dams. These estimates lead to the conclusion that the rock-fill type, with proper precautions for safety, could not be relied on to be much cheaper than a massive concrete structure the safety of which would be without question.

J. C. STEVENS,* M. AM. SOC. C. E. (by letter).†—Mr. La Rue's plan of constructing in the Colorado River a rock-fill dam 780 ft. high and a base width of more than a mile is novel and bold. He has stated the reasons the plan should not be adopted, when he says, "This mass of loose rock would not be water-tight, which feature is the most uncertain in the plan here presented."

The writer believes, however, that his plan might well be given further investigation with a view to modifying the design and method of construction so as to remove this uncertainty.

There can be little doubt that a rock-fill dam to the height proposed will stand throughout the ages and will not involve the uncertainty of stresses that would attend the design of a solid concrete dam to this unprecedented height. The only question is whether it can be made water-tight at an expense that will give it an advantage over a solid dam.

The writer thinks the plan of making a dam 200 ft. high by one blast from the canyon sides is somewhat fanciful. Under the conditions assumed, viz., 100 ft. to bed-rock and a water surface width of 450 ft., and further, assuming that the canyon sides slope $\frac{1}{2}$: 1, a fill that would raise the water 200 ft. would have a projected area of 150 000 sq. ft. The finer material would undoubtedly be washed away, leaving a fill composed of rocks from the size of cocoanuts to box cars. The voids in this mass would be at least one-third, through which the water would readily pass at a velocity of 0.5 ft. per sec. Thus, a flood of from 2 to 5 times the summer flow might pass through the fill before water reached the 200-ft. level.

It would be almost impossible to reduce this leakage to safe quantities by any amount of blanketing. For instance, for a leakage of 500 sec-ft. the velocity through the mass would be about 0.003 ft. per sec., or 250 ft. per day. Water travels faster than this in natural sand and gravel beds, moraines, etc. The first blanketing of stones, gravel, and earth would tend to fill the voids somewhat in the up-stream face of the fill, but this would reduce the velocity so that no more material would be carried into the fill. The leakage thereafter would become that through the blanket itself, and, although the velocities through it could be reduced to very low values, the aggregate amount of leakage would be great on account of the enormous area exposed to the water.

* Cons. Hydr. Engr. (Stevens and Koon), Portland, Ore.

† Received by the Secretary, June 17th, 1922.

It seems to the writer that a type of dam worth consideration would be a combination of solid concrete and rock-fill. By way of a suggestion: Unwater the river by means of a tunnel and a coffer-dam at the river level. Then build a solid concrete dam to a height of 50 ft. above the river surface, and let this dam form the up-stream toe of a rock-fill to the full height of 780 ft. The rock-fill to be faced with pre-cast reinforced concrete slabs anchored together to form a flexible facing to the fill and joining with the solid concrete dam at the toe. Heavy eye-bolts should extend through the slabs in both directions by which each could be flexibly joined to its neighbors. After placing, the joints should be filled with asphaltum.

This presupposes that the rock-fill will be placed, not dumped, and that the up-stream third of the dam will be essentially a dry wall. The slopes of the fill need not be more than 1:1 on the up-stream side and 2:1 on the down-stream side. Just how much of the rock-fill should go to bed-rock, if any, could only be determined after the character of the foundations was known.

J. H. QUINTON,* M. AM. SOC. C. E. (by letter).†—The author is entitled to much credit for his valuable contributions to the knowledge of the physical features of the Colorado River, not only in his paper, but in recent public documents.

It cannot be said, however, that he has contributed much to the knowledge of building dams in great rivers, for he proposes a plan for building a dam in the Colorado River, in which he substitutes blind force and haphazard methods founded on "beliefs", for technical skill and knowledge founded on well-known principles.

The author's idea of blasting the loose-rock portion of a dam in place is not new, as it was tried at both the Lower Otay and Morena Dams, but was not successful. The loose-rock portion of the Lower Otay Dam was composed of a mass of quarry refuse above the steel core, and of larger rock below that core.

The author proposes to build a dam, below which the water is allowed to percolate, by blasting rock from the cliffs on both sides of the canyon. Such a dam must be of such length, up and down stream, that the underground water emerging from its lower toe will not have sufficient force to carry away the sand or silt from the river bed or from the interstices of the material composing the dam. This length depends on the kind of material composing the river bed and, for each material, has a definite ratio to the head of water above the dam. For such material as that composing the bed of the Colorado River, this ratio is between 12 and 15. The flow of water under the dam may be treated as the flow of water in a pipe filled with sand or other permeable material.

The water is never allowed to pass lengthwise through the dam, and is prevented from doing so, either by a concrete wall, or an upper slope of impermeable material. The dam itself may be either permeable or impermeable. In the former case, the surface of the lower slope must be above the hydraulic grade line at all points. In the latter, the impermeable material

* Cons. Engr., Los Angeles, Calif.

† Received by the Secretary, July 10th, 1922.

below the hydraulic grade line must be heavy enough to resist the upward pressure of the water, with a reasonable factor of safety.

A good example of the former is the Laguna Dam on the Colorado, in which the ratio of length to head is 13.5, and a good example of the latter is the Granite Reef Dam on the Salt River Project, built by the U. S. Reclamation Service. The Laguna Dam, however, was not built by blasting a mass of rock into the river bed, but, like all dams which have stood the test of floods, the rock was laid in place with care. Three concrete cross-walls, each 5 ft. thick, and extending across the river bed, from bed-rock on one side to bed-rock on the other, serve to hold the loose rock in place. The top layer of rock was laid to an even slope by hand and set in cement concrete. This is a diversion dam, and is only 19 ft. high, from the bed of the river to the top of the concrete wall at the crest. The dam proposed by the author, if properly designed, would have to be at least 13.5 $\times$ 780, or 10 530 ft. long, up and down stream, would have a volume of about 106 000 000 cu. yd., and require the blasting of at least 50 000 000 cu. yd. of rock. This material, if laid carefully on the bed of the river to form a stable dam, would probably cost $1 per cu. yd., or more.

If the rock is blasted in great masses into the canyon and the river allowed to "work its sweet will" on it during the flood season, a great deal of it would be carried down stream. Much of it would also sink into the sandy bed of the river, and in a year or two probably another 50 000 000 cu. yd. of rock would be required. As designed by the author, the dam would not withstand 650 ft. of water even if all the material composing it were laid carefully in place, for the reason that the water would fill the interstices of the material. The mass would become fluid and would not stand on a slope of 4:1 or 6:1. It would creep gradually down stream, and as soon as the water of the reservoir commenced to pass over the top, it would be destroyed.

Some of the rock-fill storage dams which have stood the test of full reservoir and great storms are the Minidoka Dam (90 ft.), built in 1904, by the U. S. Reclamation Service, in Snake River, the Zuni Dam on the Zuni Indian Reservation, New Mexico (70 ft.), and the Morena Dam of the San Diego (Calif.), Water-Works (160 ft.).

Each of these dams has an impermeable or slightly permeable "curtain" or "cut-off", carefully connected to an impermeable and stable foundation. The loose-rock pile in a storage dam is not only a support, but also a blind drain for the slightly permeable material, and is generally of such dimensions as to withstand, alone, the pressure of the water, with a reasonable factor of safety against rupture or sliding. There is no record of a storage dam of the rock-fill type having been constructed without an impermeable cut-off connected to an impermeable foundation.

In this type of rock-fill, it is considered unsafe for the loose-rock part of the dam to rest on any but an impermeable foundation, as there may be considerable leakage due to imperfect work or material, in addition to the natural leakage which is to be expected through the material of the curtain. If this leakage should be sufficient to saturate the material under the loose-rock pile, settlement of the rock will occur, which would affect the stability of the

dam, and eventually cause its destruction. It will be seen that to build a properly designed rock-fill dam in the Colorado River, it would be necessary to make an excavation large enough to support the rock pile on bed-rock, or other impermeable material, such as cemented gravel. The excavation alone would cost more than a masonry or concrete dam complete, and this plan, therefore, may be dismissed as impracticable.

Nothing has been said of the advisability of building a rock-fill dam 780 ft. high, even if it were practicable. A dam of such unprecedented dimensions, and in such a great river as the Colorado, would have to be of masonry and as solid as the rock cliffs above it, in order to be safe and to inspire confidence in the people living below it. The dam proposed by the author, and his method of building it, is nothing more than a dream, or a vain imagining. "The baseless fabric of this vision" is the proposition, first to blast in place a dam 250 ft. high, with a gradual lower slope extending nearly a mile down stream. Nothing is said about the upper slope of this dam, which may be supposed to adjust itself to the angle of repose for material of this nature. Even if this could be accomplished, the water would not rise to the 200-ft. level, because it would flow freely through the interstices of the rock which forms about 50% of the mass (instead of 15% as stated by the author), and would cease to rise when that flow equalled the flow of the river above the reservoir.

The writer feels that he has said enough to show that the dam proposed by the author is not practicable. Great engineering structures cannot be founded on "beliefs" unless there are "cold facts" to justify them, and none of the latter is found in this paper. It seems unfortunate that so many people, even those in high places, should have expressed their belief that a loose-rock dam could be built by blasting cliffs into a canyon of the Colorado River, and it is hoped that this discussion will put an end to this foolish idea. Such ideas expressed by engineers, when not backed up by facts and knowledge, only cause ridicule among those who have had experience in building dams in great rivers, and give the general public a wrong impression which is sometimes difficult to eradicate.

Ernest H. Baldwin,* M. Am. Soc. C. E. (by letter).†—The magnitude of the proposition for damming the Colorado River, advanced in such an interesting manner by the author, would be sufficient in itself to attract the attention of engineers interested in this branch of engineering, but this feature, combined with many other data relative to this important but perplexing river, makes this paper extremely valuable.

The general proposition of a high dam on the Colorado River, whether at Lee Ferry or Boulder Canyon, is undoubtedly feasible and of prime necessity, but in constructing such a dam there should be no guesswork, no radical departure from the tried and tested methods that have proved successful and that require only expansion, and most careful planning, to insure their success in the Lee Ferry Dam.

* Springfield, Mo.

† Received by the Secretary, July 13th, 1922.

The writer has had experience in the blasting of rock into rivers for the purpose of forming rock-fill dams, although on a scale small in comparison with the dam proposed by the author. The most carefully laid plans will miscarry in this method of building dams, and where millions of cubic yards of rock are to be placed without interfering with irrigation, a miscalculation may be more expensive than another type of dam.

It is stated that, at the site of the Lee Ferry Dam, the bed-rock is probably overlaid with 40 ft. of boulders and sand and 60 ft. of fine sand and silt. This means that several million cubic yards of the first rock blasted would settle down, as the upper 60 ft. of sand and silt was eroded, until it rested on the bed of boulders. As the head of water increased, there would be considerable scour, with consequent leakage.

Mr. La Rue states that the first shots will blow enough rock into the river to form a dam 250 ft. high, and extending to the toe, more than a mile down stream. With the settlement due to erosion, this means about 20 000 000 cu. yd. of rock, and the blast would require about 500 tons of explosives to bring the dam to the dimensions mentioned. This is an enormous quantity of rock, too much to have misplaced.

If such a blast was feasible, the rock would pile up 100 or 150 ft. from each shore, much of it fine material, but more of it in masses of 100 to 1 000 tons, depending on the placing of the mines and the manner of loading. It would not be well mixed, the fine and the coarse rock settling at different distances from the shore. The central 100 ft. or more of the river would form a channel that would scour to the boulder formation at least, and the large masses of rock would arch, forming immense caverns that could never be filled. The material for the central, or channel, part of the dam would have to be placed by another method, and the swift current would probably transport most of that material beyond the toe.

To build a rock-fill dam as suggested by the author, would mean an extensive plant for handling and placing the material, as not more than one-third of it could be blasted into place and that could not be made tight by feasible means. The writer believes the plant required to complete the dam would be almost as elaborate and expensive as one required to build a concrete structure.

The author suggests that 10 000 000 cu. yd. of fine rock, sand, and silt might be required to tighten the dam. This, in itself, would require a large plant for loading, transporting, and placing. To be effective, the tightening material would have to be deposited in such a manner that the reservoir water would carry it at least to the center of dam, which would mean a long, tedious, and expensive process.

Should it be found, after the initial blast of about 20 000 000 cu. yd. of rock, that conditions were as previously suggested, then several million dollars would have been wasted and a good dam site spoiled.

In the writer's judgment, a dam 780 ft. high could be more economically constructed of concrete if the foundation was found to be suitable. The natural conditions at and adjoining the site seem to be favorable for the making of aggregate and the placing of concrete.

C. S. JARVIS,* M. AM. SOC. C. E. (by letter).†—The proposed plan for a 780-ft. rock-fill dam on the Colorado River is startling in many of its details, but the character and achievements of the author are such as to command a more serious consideration than would be accorded otherwise.

The remoteness of the proposed site from industrial centers might be urged against the project; but the idea of such a type of construction should be examined on its merits, for there are many dam sites more favorably located, with the same characteristics, but generally of smaller dimensions, than the one described at Lee Ferry. The question is mainly as to the practicability of such a dam, as the author specifically states in his introductory remarks.

The transporting power of running water is fairly calculable; but formulas do not take into account the action around the larger boulders. These may appear in the bed of the stream, partly submerged in rock waste or silt, and, when the flood is at its height, erosion will occur around such an obstruction. When a sufficient space has been cleared laterally and down stream, the boulder may slide or roll a short distance, and the alternate scouring and movement will be repeated. During the receding stage of the flood, the hollows down stream from the boulders are generally filled in part, so that an observer might consider such large stones safe against movement, if he neglects the effect of erosion, as described. This relentless scouring adjacent to obstructions is the element most directly opposed to the type of high rock-fill dam under discussion.

There is no doubt that, with suitable preparation and blasting, large enough masses of rock could be dislodged to create a loose rock-fill; but, to the writer, it appears improbable that a mud bank would form up stream and "make the rock-fill water-tight to an elevation of 50 to 100 ft. above the bed of the river"; that such a bank could be raised ahead of the rising water surface of the reservoir so formed; or that the rock-fill could be made reasonably water-tight in the midst of such a river, if such a mud bank should be formed and then overtopped at a height of 100 ft. If 20 000 000 cu. yd. of rock were thrown into the river gorge, as outlined by the author, the rapids formed thereby would exert their power to remove the obstruction, eroding at the down-stream toe, and rolling or sliding the protruding boulders into the hollows thus formed, until the rock-fill had spread, settled, and displaced sufficient of the river sand and gravel to insure stability for that particular stage of flow. A higher flood stage would probably cause a resumption of the process of erosion and shifting. During the low-water stage, the entire flow of the river might run through the rock-fill, and the erosion and transportation of the finer materials would continue, mainly from the up-stream section of the dam.

The writer served as engineer on one irrigation project where time limits and flood conditions required the placing of a 20-ft., concrete diversion dam partly on bed-rock and partly on a rock-fill in the midst of a rapids in the river channel. It was well known that leakage would result, with no danger to the structure. A rock and earth-fill dam was to adjoin the concrete section and extend to the opposite bank on and immediately up stream from the rock-fill

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* Capt., Corps of Engrs., U. S. A., Camp Lewis, Wash.

† Received by the Secretary, July 31st, 1922.

in the river bed. The structures were built during flood stages of the stream, and maintained safely; but to stop the recurrent and persistent leaks through this rock-fill required the placing of an additional volume of finer materials about equal to the volume of the structure as originally planned; and, finally, during a low stage of the river, a cut-off wall was placed through a part of the river bed, at the up-stream limit of the dam, to prevent the recurrence of leaks and slow erosion of the finer materials.

The construction of several rock-fill dams with puddle cores on glacial drift, together with observations on these structures in service, and the lateral and terminal moraines which serve as the retaining embankments for reservoirs and lakes of great depth, have convinced the writer that a combination of rock-fill and hydraulic-fill may be built and maintained safely at such a height as the author has suggested; but a pre-requisite for making it reasonably water-tight and dependable would be the positive checking of the underflow and the control of the river during construction, to prevent the segregation and loss of the finer materials.

Those who have had to construct measuring weirs in rocky stream beds with the water at high stage need not be reminded of the difficulty in making the structure water-tight, especially at the junction with the stream bed. The volume of finer materials required to complete the dam that holds back only a 2 or 3-ft. depth of water may be doubled or trebled, because of the persistent erosion and loss of the finer particles through the rock-fill.

The extensive studies and writings of the author on the utilization of various Western rivers, and his location of the most feasible dam sites and storage basins, are valuable contributions to professional knowledge.

Referring to the author's Conclusion No. 9,* "Should either the rock-fill or a concrete dam be overtopped by a flood, the damage might be sufficient to cause failure", it seems improbable that a concrete structure of such magnitude would be designed or constructed so as to permit failure if overtopped, whereas the rock-fill would certainly be lost under such a condition, and the resulting damage and loss in the lower valleys would be incalculable.

In view of these considerations and the uncertainties that would envelop the construction, the cost, and the behavior of the rock-fill dam as proposed, it seems a safe conclusion that any dam of unprecedented height at the proposed or similar sites will be of masonry, founded on bed-rock, or of rock-fill with adequate core-wall.

* *Proceedings*, Am. Soc. C. E., April, 1922, p. 851.

MEMOIRS OF DECEASED MEMBERS

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

SYLVAN EARL GANSER, M. Am. Soc. C. E.*

DIED APRIL 14TH, 1922.

Sylvan Earl Ganser, the son of Daniel Z. and Martha A. Ganser, was born at Harlan, Iowa, on December 21st, 1879. He was graduated from the High School at Harlan in 1898, and attended Cornell College, at Mt. Vernon, Iowa, receiving his B. S. degree in 1904 and C. E. degree in 1906.

During the summer vacations of his college course, Mr. Ganser was employed as Surveying Assistant on the Illinois Central Railway and the Chicago and Northwestern Railway.

In 1905, he entered the service of the Union Pacific Railway Company as an Assistant Engineer on Maintenance of Way and was assigned to the Colorado Division, where he had supervision of minor improvements and maintenance work.

In February, 1907, he was employed by the Atlanta, Knoxville, and Northern Railway Company, a subsidiary of the Knoxville and Nashville, and, later, was transferred to second-track construction on the Louisville and Nashville Railroad as Resident Engineer. This work included heavy rock excavation, driving and lining of tunnels, and the enlargement of the Atlanta Terminals. Mr. Ganser was a member of a large organization engaged on the construction of new railroad lines, which, at that time, was in immediate charge of J. E. Willoughby, M. Am. Soc. C. E., Chief Engineer of Construction.

For one year he was employed by the Michigan Central Railway Company as Inspector on the placing of forms, concrete, and steel tubes for the Detroit River Tunnel, which connects Detroit, Mich., with Windsor, Ont., Canada.

In August, 1909, Mr. Ganser again entered the service of the Union Pacific Railway Company, as Assistant Engineer of Construction, in charge of the Pleasant Valley Line, on the North Port Extension, Denver Terminals, and the Fort Collins Line, and 250 miles of estimates and surveys, from North Platte, Nebr., to Ogden, Utah.

In 1911, he decided to specialize in structural steel design. He entered the Massachusetts Institute of Technology for additional technical training in September of that year and remained there for two years.

In June, 1913, he entered the service of the Duluth and Iron Range Railway Company, and made extensive studies for a gravity yard and a number of buildings and facilities for the Ore Terminal at Two Harbors, Minn.

From March, 1914, to September, 1915, Mr. Ganser was employed by the firm of Toltz, King and Day, as a Structural Engineer. In this capacity, he was responsible for, and contributed quite largely to, the success of the struc-

* Memoir prepared by H. E. Stevens, M. Am. Soc. C. E.

tural work on the Northern Pacific-Great Northern Office Building at St. Paul, Minn.

From September, 1915, to August, 1916, he was employed by the American Hoist and Derrick Company of St. Paul, and was responsible for the design of a large Government derrick for the Panama Canal and other machines of considerable importance.

In 1916, Mr. Ganser entered the service of the Northern Pacific Railway Company, with which he continued until his death on April 14th, 1922. During this time, he contributed to the design of many structures, the most important of which was a reinforced concrete ore dock at Superior, Wis.

His death resulted from an operation, and was unexpected. His general health, while not of the best, had not interfered with his duties, and he was employed up to the time he entered the hospital.

Mr. Ganser was married in 1906 to Miss Bessie Stewart who, with his parents, survives him.

In character, his strongest traits were his uprightness, hatred of deceit, devotion to duty, love of home, hospitality, and charity. Mr. Ganser was a most kindly man, very humorous, and was deeply appreciated and greatly loved by his many friends. In all things, he was a man and a gentleman.

He was a member of the Official Board of Trinity Methodist Episcopal Church and a member of the Sunday School Board. He was also Vice-President of the Twin City Chapter of the American Association of Engineers.

Mr. Ganser was elected an Associate Member of the American Society of Civil Engineers on January 2d, 1912, and a Member on January 18th, 1921.

CHARLES SEWALL GOWEN, M. Am. Soc. C. E.*

Died October 19th, 1909.

Charles Sewall Gowen, the only child of James and Emeline (Cummings) Gowen, was born at Barnstable, N. H., on February 14th, 1851. His father, who died in 1854, was descended from a Scotch-Irish ancestor who, with a large number of compatriots, came to America in the middle of the 18th Century. His mother was a descendant of Isaac Cummings, who came from Scotland in 1644 and settled in Ipswich, Mass.

Mr. Gowen received his early education in the public schools of Clinton, Mass., and was a student at the Massachusetts Institute of Technology from 1867 to 1869.

In October, 1869, he entered the service, as an Assistant Engineer, of the late James B. Francis, Past-President, Am. Soc. C. E., Agent and Engineer of the Locks and Canal Company, of Lowell, Mass., remaining there until May, 1876. Mr. Gowen's experience while with Mr. Francis was of great value to him in his later work.

In May, 1876, Mr. Gowen joined the forces engaged on the additional supply of the Boston Water-Works, serving until May, 1880, as Rodman, Leveler,

* Memoir prepared by Jules Breuchaud and Robert Ridgway, Members, Am. Soc. C. E., and Fred B. Rogers, Esq., New York City.

and Assistant Engineer. Afterward, and until August, 1881, he was an Assistant Engineer in charge of the Western Division of the Boston Improved Sewerage, and, subsequently, he was made Resident Engineer and Superintendent of Construction of the Boston Water-Works, having charge of Dam and Basin "IV" of the Sudbury Supply near Ashland, Mass., until June, 1883. He then accepted an appointment as Assistant Engineer in charge of hydrography, with the Philadelphia Water Department, in investigations for a new source of supply from the Schuylkill River, and remained in this position until March, 1884, when he was appointed Assistant Engineer by the Aqueduct Commissioners of New York City, a body created by a law passed in the preceding year to obtain an additional water supply for the city.

During the summer and autumn of 1884, Mr. Gowen was engaged on surveys for reservoir sites and on the location of the "New" Aqueduct line from Croton Lake to the Harlem River, as well as on other studies in preparation for the building of this great Aqueduct, which, with the exception of a few short stretches of cut-and-cover and some short lengths of soft-ground tunnels, was in rock tunnel from the head-works at the Old Croton Dam to the gate-house at 135th Street and Convent Avenue, Manhattan, a total distance of 30¾ miles. The Aqueduct drops below the hydraulic gradient near the city line and continues under pressure a distance of 7 miles to the 135th Street Gate-house, reaching a maximum depth of 300 ft. below tide-water at the Harlem River Crossing, approximately 430 ft. below the gradient. There is also a short inverted siphon under "Gould's Swamp" near Tarrytown, N. Y. The remaining Aqueduct at grade has a horseshoe cross-section, 13.53 ft. high by 13.60 ft. wide at the springing line, and was designed for a capacity of 300 000 000 gal. per day, whereas the circular pressure tunnel below the city line was designed to carry 250 000 000 gal. daily. The conduit was brick-lined throughout. One of the details of the preliminary work was the accurate measuring of the line, which was done by methods developed by Mr. Gowen and Alfred Craven, M. Am. Soc. C. E. The measurements were made on the slope and were reduced to the horizontal after corrections were made for sag, temperature, and error in graduations. Bronze bolts were set on line in ledge rock or in granite monuments embedded in concrete at intervals of 1 000 ft. or more and were numbered and stationed. This work was done quickly and economically and reflected credit on Mr. Gowen and others who were responsible for the methods and the results. It proved its value during the construction period which followed. Mr. Gowen was an excellent surveyor and, when the tunnel driving was begun, established methods of carrying the lines and grades into the headings, which not only eliminated errors and insured accuracy, but also caused a minimum of interference with the contractor's operations.

When the Aqueduct work was placed under contract about the end of 1884, Mr. Gowen was made a Division Engineer and placed in charge of Division No. 1, which included the complicated gate-house and other head-works at the Old Croton Dam and Shafts 0 to 4, inclusive, of the Aqueduct. Shaft 0 was an inclined shaft, about 300 ft. long, and Shafts 1 to 4, inclusive, were vertical shafts, 250 to 350 ft. in depth. Later, a re-organization added Shafts 5 and 6

to Mr. Gowen's Division. Under his direction, the shafts were sunk and the tunnels from them were driven. A second re-organization in 1888 placed him in charge of the completion of the 13 miles of Aqueduct from Shafts 0 to 11, inclusive.

Soon after the masonry lining work was begun, much trouble was encountered, due to the lack of co-operation on the part of the contracting firm and the dishonest practices of some of its employees. The work was slighted in many ways, mortar was omitted, cavities were left behind the brick lining, and the work was greatly demoralized. Politics played its part, affecting seriously the morale of the inspection force. Mr. Gowen stood firm against these practices and, in spite of many attacks made on him by his opponents, insisted on having the defective work corrected. His resolute stand, in which he was supported by his subordinates as well as by the engineers of other divisions, led to an investigation of the work by the Legislature in 1888. This was followed by a re-organization of the Commission in the same year and the repair and reconstruction of the defective work at the expense of those responsible for it. The late Alphonse Fteley, Past-President, Am. Soc. C. E., who had been made Chief Engineer in 1889, stated in his report to the Aqueduct Commissioners covering the years 1887-95:

"Mention should be made, however, of the able services performed by * * * Division Engineer Charles S. Gowen * * *. Messrs. Rice, Gowen, and Craven especially have rendered to the City valuable service by successfully enforcing and superintending, under serious difficulties and hardships, the repairs of the defective parts of the Aqueduct."

Some of the difficulties encountered by the engineers in carrying out the work are shown in detail in the same report.

On the practical completion of the Aqueduct, Mr. Gowen, in 1890, was placed in charge of the construction of Reservoir "M" on the Titicus River, near Purdy Station, N. Y., one of the several reservoirs constructed at, and subsequent to, that time in the development of the Croton water-shed. The dam was a rubble masonry structure, faced with cut native stone, of a maximum height of about 135 ft., with earth wings, the latter containing rubble masonry cores. Its total length was 1 519 ft. The rolled earth embankment of the north wing was more than 100 ft. high and the whole structure was considered a work of considerable magnitude at that time. The dam impounded more than 7 000 000 000 gal., and the construction cost, with the roads and other appurtenances, was more than $1 000 000. Mr. Gowen gave his earnest attention to the organization of the job and established standards for quality of work which, with the rigid inspection of his subordinates and the co-operation of the contractor, resulted in an excellent structure.

The Titicus Dam was completed in 1895, but, in October, 1892, Mr. Gowen had relinquished the control of the work to take charge of the construction of the New Croton Dam, the contract for which was let in the same year. The Croton Dam is still one of the great dams of the world and, at the time it was designed, attracted the attention of hydraulic engineers everywhere. Its greatest height was about 300 ft., and the maximum depth of its foundations, below the river bed, was about 150 ft. One of its features is the curved spill-

way, 1 000 ft. long on the north side, the greater part of the length of which is parallel with the contours of the hill against which the dam abuts. The capacity of the reservoir is about 30 000 000 000 gal. The disintegrated limestone underlying the foundation at the deepest point gave much trouble, and the manner in which this feature of the work was treated is well described in a paper* by Mr. Gowen entitled "Foundations of the New Croton Dam". Before the dam was entirely finished, certain radical changes were made in the design of the south wing, calling for the destruction of the earth bank and core-wall which had been built there and the substitution of a masonry section. The changes were not approved by Mr. Gowen and are the subject of his paper,† "The Changes at the New Croton Dam". This imposing engineering structure with which Mr. Gowen's name is so closely identified, was finally completed by the end of 1906, together with the 32 miles of new highway about the reservoir. It constitutes a wonderful monument to him and to the contractors who built it.

Mr. Gowen did not wait for the completion of the Croton Dam, but on August 31st, 1905, resigned from the service of the Aqueduct Commissioners and thereafter became engaged in consulting work. Until he was taken ill in 1909, he had hardly known a day's illness. In fact, his good health was a matter of comment among his associates. His illness continued for months until his death on October 19th, 1909, at his home in Ossining, N. Y.

Mr. Gowen had the spirit of a Spartan. Duty came first with him, and he could never understand why personal interests or convenience should stand in the way of a man's work. His reserve was sometimes misunderstood by those who knew him casually, and it was only on a closer acquaintance that one realized the more kindly aspects of his nature. There was little compromise in his make-up, and he had no patience with those who would slight their work for profit or for any other reason. The following is quoted from a memoir prepared by two of his friends and published in an Ossining paper soon after his death:

"A casual glance would give one the idea that Mr. Gowen was deeply reserved and self-absorbed, but an intimate acquaintance with him revealed the most charming qualities. He was schooled in strict integrity and was that most perfect creature of God's handiwork, 'an honest man'. His most pronounced characteristics were justice and fairness in his relations with those with whom he was associated. Political influence did not sway his action and in all things he was the soul of honesty and honor."

The same memoir contains this reference to his work at the Croton Dam:

"His administration of the work was characterized by the same rigid attention to detail which had marked his supervision of whatever he had previously undertaken. He zealously guarded the City's interests and was quick to detect and forestall any proposition that might lead to unnecessary expenditure. 'Now let us be severely logical' was a favorite expression in dealing with a perplexing problem. Eminently a man of the courage of his convictions, just and upright to an extreme, and the uncompromising foe of whatever looked like 'graft' and extravagance. A strict disciplinarian but, withal, a most loyal and steadfast friend to every man whose conduct justified his confidence. Indomitable energy was another strong characteristic. No degree of heat or

* *Transactions*, Am. Soc. C. E., Vol. XLIII (1900), p. 469.

† *Transactions*, Am. Soc. C. E., Vol. LVI (1906), p. 32.

cold, snow or blizzard, was sufficient to block the way, were it in the power of man to overcome the difficulties."

Mr. Gowen made many friends in and about Ossining, where he lived from 1885 until his death. He was interested in the community life and at the time of his death was President of the Briarcliff Golf Club, which office he had held since the organization of the club. He was also a member of the Shattemuc Yacht and Canoe Club of Ossining.

He contributed a number of papers and discussions to the *Transactions* of the Society, and, in addition to the two papers previously mentioned, he was the author of "The Effect of Temperature Changes on Masonry".*

He was married on June 1st, 1882, to Miss Alice J. Fellows, the daughter of Mr. James K. Fellows, of Lowell, Mass. Mrs. Gowen, with two sons and two daughters, survived him.

Mr. Gowen was elected a Member of the American Society of Civil Engineers on March 7th, 1888. He served as a Director from 1904 to 1906, and during that time was a member of the Finance Committee of the Board of Direction.

CORNELIUS VAN VORST POWERS, M. Am. Soc. C. E.†

Died June 18th, 1922.

Cornelius Van Vorst Powers, the son of William P. and Mary B. (Van Vorst) Powers, was born in Jersey City, N. J., on November 4th, 1860. He received the degree of Ph. B. from the School of Mines, Columbia University, New York City, in 1882. After his graduation, he spent some time traveling in Europe and was engaged in work (other than engineering) until February, 1885.

Mr. Powers began his engineering career with the Aqueduct Commission of New York City, then engaged in constructing the so-called New Croton Aqueduct from Croton Dam to New York City. He served with this Commission until June, 1900, rising successively from junior engineering positions to that of Assistant Engineer. He was engaged on the construction of the Aqueduct Tunnel in the upper part of the Borough of Manhattan, New York City, and had charge of the construction of a part of the pipe line, consisting of a battery of 48-in. pipes, eight in number, where it left the terminal gate-house at 135th Street and Convent Avenue, four of the pipes continuing to the reservoir in Central Park. He also had charge of a blow-off from Pressure Shaft No. 24 to the Harlem River. The experience gained in the building of this great tunnel was reflected in his work on the New York City Rapid Transit construction with which he was later connected. On the completion of the pipe line and blow-off, he was assigned to the Croton River Division in Westchester County, where he had charge of the surveys and studies for additional reservoirs and for maps for the condemnation of lands to be acquired, as well as for the necessary relocation and reconstruction of railroads, highways, and highway bridges, and the estimates of cost.

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* *Transactions,* Am. Soc. C. E., Vol. LXI (1908), p. 399.

† Memoir prepared by Robert Ridgway and Charles D. Searle, Members, Am. Soc. C. E.

In June, 1900, Mr. Powers was transferred to the Engineering Staff of the Board of Rapid Transit Railroad Commissioners, New York City, at the time when work was begun on the construction of the first subway, and served with that Commission and its successors, the Public Service Commission, First District, State of New York, the Transit Construction Commissioner, and the Transit Commission, on the work of constructing the New York City Rapid Transit Railroads. His first work on rapid transit construction was as Assistant Engineer in charge of the construction of the two-track subway on Broadway, from 135th Street to Dyckman Street, a large part of which was in deep rock tunnel, including two arched tunnel stations with shafts, in which were installed elevators and stairways providing access from the surface. At these stations, the tunnel was excavated wide enough to span the two tracks and the side platforms of the stations.

Mr. Powers was appointed Division Engineer in March, 1903, and, until January 1st, 1917, he supervised the construction of the subway and elevated lines in Upper Manhattan and The Bronx, which were built under contract with the Commissions. He also supervised the surveys for new rapid transit lines, as well as the construction and the certification of the reasonable cost of the third-tracking and extensions of the lines of the Manhattan Elevated Railroad Company in these Boroughs, the latter work being done by the Company under certificates approved by the Public Service Commission. During this period, Mr. Powers also assisted in the preparation of engineering data for the city's defense in the arbitration proceedings growing out of the contractors' claims on the contract for the original subway, as well as in the writing of the contracts and specifications for certain later lines, covering construction in Lower and Upper Manhattan and in The Bronx.

As Division Engineer in Charge of Construction, the value of the work which Mr. Powers supervised approximated $35 000 000, and included deep and difficult tunnel and subway construction, some of which was adjacent to closely built-up sections in the city, as well as the construction of a two-track tunnel under the Harlem River, which was built by novel methods, and another four-track tunnel under this same river, which was constructed in a manner somewhat similar to that used for the tunnel of the Michigan Central Railroad under the Detroit River. The value of third-tracking and extension work of the lines of the Manhattan Elevated Railroad Company approximated $20 000 000.

Mr. Powers' work in connection with the city's defense in the arbitration proceedings, as well as his work in the writing of the contracts and specifications, was so thorough and fair that it has been spoken of in high terms by those who were familiar with it.

From January, 1917, he was the Division Engineer in Charge of the Bureau of Contract Adjustment, which position he held at the time of his death on June 18th, 1922. The result of the painstaking, minute, and clear analysis of the contractors' claims which he made personally and directed during the time he was the head of this Bureau, have been and will be of great value to the city.

Mr. Powers was a man of modest disposition, high ideals, and absolute integrity; he was conscientious almost to a fault. He was well informed, with a keen sense of humor, and was a good friend, always ready to help in time of misfortune. He was held in high and affectionate esteem by his associates. It has been deservedly said of him that he was a Christian gentleman. He was fond of outdoor life, an ardent fisherman, and had a great fondness for flowers, which he cultivated with much pleasure. He was an excellent amateur photographer and, in the earlier part of his career, delighted in taking pictures of points of interest on his work and, later, on his fishing trips. An inspection of the reports of the Aqueduct Commission will show many good examples of his work among the illustrations. He worked with his usual zest and interest until the evening of the day before he was stricken.

Mr. Powers was unmarried and is survived by his brother, William Van Vorst Powers.

He was a member of the University Club of New York City, Columbia University Club, Psi Upsilon Fraternity, American Association of Engineers, Municipal Engineers of New York, of which he had been Vice-President and Director, and the Dutch Reformed Collegiate Church of St. Nicholas, New York City, in the activities of which he took great interest.

Mr. Powers was elected a Member of the American Society of Civil Engineers on March 1st, 1905.

FRANK EPHRAIM CHESLEY, Assoc. M. Am. Soc. C. E.*

Died January 9th, 1922.

Frank Ephraim Chesley was born in Center Township, Fayette County, Iowa, on May 8th, 1879. He was educated in the country schools and was graduated from the Fayette High School in 1896. In March, 1901, he entered the State University of Iowa and was graduated in June, 1904, with the degree of B. S. in C. E. He received the degree of C. E. from the University in 1912.

From 1904 to 1908, Mr. Chesley was engaged in general engineering work as Inspector and Instrumentman on different engineering projects. From 1908 to 1910, he was employed as Resident Engineer in charge of waterworks, sewage disposal plants, electric lighting plants, and paving work in various towns in Iowa. For a short period in 1912, he served as an Inspector, in the U. S. Corps of Engineers at Sterling, Ill., after which he was again engaged in municipal engineering work in Pennsylvania and elsewhere.

During subsequent years, Mr. Chesley was engaged in an engineering capacity in connection with municipal improvements and industrial works, serving as Resident Engineer in charge of the construction of rolling mills, blast furnaces, open-hearth furnaces, and other work connected with steel mills. He was also engaged for some time in connection with the U. S. Government Munitions Plant at Neville Island.

* Memoir prepared by J. L. Ludlow, M. Am. Soc. C. E.

In 1919, he joined the staff of The Ludlow Engineers at Winston-Salem, N. C., doing general office work and outside practice and, later, was assigned to the position of Resident Engineer on sewer construction at Goldsboro, N. C.

Mr. Chesley was not a man of robust health, but he was very energetic, persevering, and loyal to his duty. His work as an engineer, although brief, the ability he displayed, and his intense devotion to his Profession gave abundant promise of a useful and honorable career had his life not been terminated at such an early age.

He was a member of the Masonic Fraternity. A few months before his death, he had received a certificate as Registered Engineer under the new License Law of the State of North Carolina.

On August 15th, 1911, he was married to Mollie L. Livecay, of Halifax, N. C., who, with his mother, survives him.

Mr. Chesley was elected an Associate Member of the American Society of Civil Engineers on December 31st, 1913.

PAPERS IN THIS NUMBER

"EXPERIMENTS WITH MODELS OF THE GILBOA DAM AND SPILLWAY." By R. W. GAUSMANN and C. M. MADDEN. (To be presented October 4th, 1922.)

"ENGINEERING GEOLOGY OF THE CATSKILL WATER SUPPLY." By CHARLES P. BERKEY and JAMES F. SANBORN. (To be presented October 4th, 1922.)

TECHNICAL PAPERS PRESENTED AT THE ANNUAL CONVENTION AT PORTSMOUTH, N. H., June 21st, 1922.

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PROCEEDINGS

This Society is not responsible for any statement made or opinion expressed in its publications.

SOCIETY AFFAIRS

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ITEMS OF INTEREST

The Committee on Technical Activities and Publications will be glad to receive communications of general interest to the Society, and will consider them for publication in *Proceedings* in "Items of Interest". This is intended to cover letters or suggestions from our membership concerning matters which are not of a technical character. Such communications, however, must not be controversial or commercial.

Conference of Engineers of Texas on Program for Water Conservation and Flood Protection

A conference of the engineers of Texas was called at Austin, Tex., on August 7th, 1922, by Governor Pat M. Neff, for the purpose of working out a comprehensive program for the conservation of flood waters and the preserva-

tion of the overflowed lands of the State. The Governor stated that if such work is to be done in a proper manner the Civil Engineers of Texas must take the lead in the movement. At this conference, T. U. Taylor, M. Am. Soc. C. E., acted as Chairman and E. N. Noyes, M. Am. Soc. C. E., as Secretary.

Addresses were delivered by Samuel Fortier, M. Am. Soc. C. E., U. S. Department of Agriculture, N. C. Grover, M. Am. Soc. C. E., Chief Hydraulic Engineer, U. S. Geological Survey, Col. Glenn S. Smith, Acting Director, Topographic Division, U. S. Geological Survey, Maj. B. B. Brown, Assistant District U. S. Engineer, Galveston, Tex., and Maj. W. N. Vance, Engineer, 8th Corps Area, Fort Sam Houston, Tex., all of whom promised full assistance and co-operation by the Departments which they represent.

On motion by John A. Norris, M. Am. Soc. C. E., Chairman, State Board of Water Engineers, Governor Neff appointed an Advisory Council of Engineers to co-operate with the State Reclamation Department and the State Board of Water Engineers in all matters pertaining to the movement for the control, conservation, and economic utilization of the water resources of the State. The Advisory Council, as named, consists of Messrs. T. U. Taylor, John B. Hawley, E. N. Noyes, C. Terrell Bartlett, E. E. Sands, W. F. Shaw, Fred A. Jones, J. C. Nagle, F. A. Merritt, Vernon L. Sullivan, E. H. Sellards, R. A. Thompson, and W. B. Tuttle.

On motion by J. H. Brillhart, M. Am. Soc. C. E., the delegates from each principal water-shed selected a Committee of Engineers to assist in gathering such data as would be of service in solving the water problems of the State, these results to be reported both to the State Reclamation Department and to the State Board of Water Engineers.

A Committee on Resolutions consisting of Messrs. John B. Hawley, A. Tamm, and E. B. Cushing, submitted resolutions recommending the mobilization of all available engineering talent, including State and Federal forces, and the Engineering Profession in general, to develop the data essential to the prosecution of such reclamation enterprises, and requesting the State Legislature to appropriate adequate funds for Weather Bureau work, in collaboration with the Federal Weather Bureau, and that ample appropriations be made for extending the activities of the State Reclamation Department and the State Board of Water Engineers in securing data on which to plan and design works for the control and utilization of the flood waters of the rivers of Texas.

The resolutions also recommended and instructed the Advisory Board to attend the State Conference on the conservation of flood and surface waters, the reclamation of lands needing irrigation, and the protection of lands subject to overflow, which was held in Waco, Tex., on August 16th, 1922, and further instructed the Chairman to appoint twenty delegates to attend such gathering.

Conference at Waco, Tex., August 16th, 1922

The Engineer Delegates together with other bodies interested in conservation and flood control met and formed a permanent organization. Officers were elected and a committee was appointed the duty of which is to prepare and present to the Legislature all necessary legislation for such work and to co-

operate with the Federal Government to promote these enterprises. About 188 representatives were present at the meeting.

Plans for Engineering Library at Denver, Colo.

Largely at the instance of the Colorado Engineering Council, plans are under way to establish an important engineering library in Denver, for the use of Colorado engineers. The funds received from engineer license fees are available to buy books and the State Board of Engineer Examiners will use such funds in this way. The valuable library of the Colorado Scientific Society will form the nucleus of the new institution, which will be housed and administered by the Denver Public Library, with the co-operation of a committee representing the various organizations interested.

At the request of these bodies, Harrison W. Craver, of New York City, Director of the Engineering Societies Library, visited Denver during August, 1922, to consult concerning plans for the organization and administration of the proposed library.

Arch Dam Investigation

Arch dam design and construction vary widely, ranging from thin concrete sections to the extremely thick Gilleppe Dam in Belgium. There is a dearth of observed facts on which to base good practice. Engineering Foundation has been asked to organize a co-operative investigation which would include observations on existing structures and those which may be built in the near future, so that a statement of facts, and possibly a theory based thereon, would furnish engineers with a better guide. Many important arch dams are said to be contemplated in the western part of the United States. Engineering Foundation has assurances of help from a number of engineers, the U. S. Reclamation Service, the Department of Public Works of California, and corporations owning dams. Information about existing structures, or suggestions, would be acceptable. Further information will be sent, on request, by the Secretary of the Foundation, Alfred D. Flinn, M. Am. Soc. C. E., 29 West 39th Street, New York.

National Personnel Association Organized

Leaders of organized engineering, representatives of large industries, insurance companies, railroads, and publishers, and members of university faculties have organized the National Personnel Association. The announced purpose of the movement is "to advance the understanding of the principles, policies and methods of creating and maintaining satisfactory human relations within commerce and industry." The new organization takes over the activities of the National Association of Corporation Training and the Industrial Relations Association of America.

An Executive Committee and a Board of Directors have been chosen. W. W. Kincaid, of Niagara Falls, N. Y., head of the Spirella Company, has been named President. Earl B. Morgan, the Curtis Publishing Company,

Philadelphia, Pa., is Vice-President, and Montague A. Clark, the E. I. DuPont de Nemours and Company, Arlington, N. J., is Treasurer. W. J. Donald, 20 Vesey Street, New York City, is the Managing Director and Secretary.

International Chamber of Commerce

The Second General Meeting of the International Chamber of Commerce will be held in Rome, Italy, March 18th to 24th, 1923. It is the desire of the American Section of the International Chamber of Commerce to create a broader interest in international affairs, and chambers of commerce and trade organizations in the United States have been invited to participate in the meeting at Rome. Invitations have also been sent to a large number of business men throughout the country.

Plans have been made whereby those who attend the meeting may have an opportunity to study commercial and economic conditions in the Mediterranean countries, the Near East, and Western Europe. Applications to join this tour, which sails from New York City on February 10th, 1923, should be addressed to Lacey C. Zapf, Secretary, American Section, International Chamber of Commerce, Mills Building, Washington, D. C.

BIOGRAPHICAL SKETCHES OF CANDIDATES FOR OFFICES TO BE FILLED AT THE ANNUAL ELECTION, JANUARY 17th, 1923.

Charles Frederick Loweth

(Candidate for President)

Born March 3d, 1857, at Cleveland, Ohio (Oberlin College, Ohio, 1878-79; Hon. C. E., Univ. of Wisconsin, 1915)—Prior to 1883, employed in engineering capacity on railroad surveys and construction in Ohio, Illinois, Kansas, and Iowa, as Bridge Draftsman, with Edge Moor Iron Co., Wilmington, Del., and with a bridge company in Iowa: 1883-1901 engaged in private practice as Cons. Civ. Engr., in St. Paul, Minn.; during this period served professionally more than 100 municipalities throughout the Northwest, with reference to water supplies, sewerage, electric lighting, bridges, and other engineering work, for most of which was responsible for design and supervision of construction, many of the projects being of considerable importance; also, served professionally the Chicago, Milwaukee & St. Paul Ry., Northern Pacific Ry., Minneapolis, St. Paul & Sault Ste. Marie Ry., Oregon R. R. & Nav. Co., Minneapolis & St. Louis R. R., St. Paul Union Depot Co., and several other railroads, these services including responsibility for design and construction of many large and important bridges and other structures: March 1901-Dec. 1910 Engr. and Supt. of Bridges and Bldgs., Chicago, Milwaukee & St. Paul Ry.: December 1910 to date Chf. Engr., Chicago, Milwaukee & St. Paul Ry., having general charge of all engineering activities; was in responsible charge of many important portions of the construction of the Company's Pacific Coast Extension, which was one of the largest individual railroad construction projects of recent years.

George Stewart Davison

(Candidate for Vice-President)

Born September 21, 1856, Pittsburgh, Pa. (Rensselaer Polytechnic Inst., C. E., 1878)—1878-1881 Eng. Dept., Pennsylvania Lines, Pittsburgh; Eng. Dept., Santa Fé R. R., Topeka, Kans.; hydrographic work on Govt. Eng. Corps on Arkansas, Mississippi, and Missouri Rivers; Maintenance-of-Way Dept., Pennsylvania Lines: 1882-1889 Chf. Engr. on Constr. of Pittsburgh Chartiers & Youghiogheny Ry., subsequently, Engr. of Maintenance and Supt.; Chf. Engr. on reconnaissance and location of original plan to connect by rail the Carnegie Steel Co.'s Pittsburgh plants with Lake Erie ports: 1890-1899 member of the firm of Wilkins and Davison, Pittsburgh, conducting a general engineering practice: 1900-1901 Gen. Mgr. of portion of street railway system of Pittsburgh; Cons. Engr. Cherokee Mine, California: 1902 to date engaged in various business enterprises, comprising, at present, eighteen industrial and nine public utility companies, connection with which requires knowledge of and experience in technical matters.

Anson Marston

(Candidate for Vice-President)

Born May 31, 1864, Seward, Ill. (Liberal Arts Work, Berea Coll., Berea, Ky., 1884-85; Cornell Univ., C. E., 1889; Graduate Work, C. E., Cornell Univ., winter of 1892-93)—Summers of 1886, 1887, and 1888, railway location and construction, Ill. Cent. Ry.: 1889 Res. Engr., Indiana & Lake Mich. Ry.: 1889-1891 Transitman, Res. Engr., and Chf. of Party, Mo. Pac. Ry., Arkansas and Louisiana: 1891-1892 Res. Engr. in charge of construction of Ouachita River Bridge, Columbia, La.: 1892-1919, Professor of Civ. Eng., Iowa State Coll., Ames, Iowa: 1904 to date, Dean of Eng., Iowa State Coll.; as College Engr., superintended construction of several buildings and designed and constructed college water supply and sewer systems, including first complete sewage disposal plant in Iowa; 1892 to date, maintained consulting practice in bridge, water supply, and sewerage engineering; acted as Cons. Engr. or designed and constructed water supply and sewerage systems for several towns and cities in Iowa, Minnesota, and South Dakota; associated in valuation of water-works of Waterloo, Iowa, and Freeport, Ill.; Cons. Engr. on concrete arch bridges at Des Moines and Cedar Rapids, Iowa; on flood protection channel at Cedar Rapids, Iowa, etc.: 1904 to date, Director of Eng. Experiment Station, Iowa State Coll., Ames, Iowa; among the more noteworthy Station investigations may be mentioned those in Drainage Engineering, Highway Engineering, Power Plants, Proportioning of Concrete, Bacterial Water Analysis, Sewage Disposal, Tests of Sewer Pipe and Drain Tile, and especially in the theory of loads on pipes in ditches and in culverts projecting above the surface of solid ground adjacent: 1904 to date, Member (*ex officio*) Iowa State Highway Commission: 1917-1918, Major of Engrs., Iowa National Guard and U. S. Army, commanding 1st Bn. Iowa Engrs. and 1st Bn. 109th Engrs., at Camp Dodge, Iowa, and Camp Cody, New Mexico: September-December, 1918, Lt.-Col. of Engrs., U. S. Army, commanding 97th Engrs., Camp Leach, Washington, D. C.: author of an American Correspondence School text on "Sewers and Drain"; author and joint author of several Research Bulletins.

Glenn Dickinson Holmes

(Candidate for Director, District No. 3)

Born June 17, 1873, Alabama, N. Y. (Cornell Univ., C. E., 1896)—1897-1898 Asst. Engr. New York State Canals, in charge of 5 miles of reconstruction: 1898-1899 surveys and preliminary investigation with the U. S. Board of Engrs., Deep Waterways: 1899-1900 Engr. in charge of special investigations and surveys for water-power development for W. C. Johnson of Niagara Falls: 1900-1901 Asst. Engr. New York State Canals, in charge of topographic surveys of 55 miles of canal, mapping, and preliminary estimates: 1901-1903 Asst. Engr. Improvement of Water Supply, Philadelphia, on design and later in charge of construction of the slow sand filter plant: 1903 (8 months) Asst. Engr., Commission of Additional Water Supply, New York City, in charge of field work, investigation, reservoir sites, etc.: 1903-1905 Expert Computer,

New York State Canals, on hydraulic problems: 1905-1907 Engr. of Water Supply, New York State Canals, in charge of all work in connection with securing an adequate supply of water for the summit level of the Barge Canal, including dams, reservoirs, feeders, etc.: 1907 to date, Chf. Engr., Syracuse Intercepting Sewer Board, work includes sewer construction, stream improvement, flood prevention, and sewage treatment and disposal.

Ezra Bailey Whitman

(Candidate for Director, District No. 5)

Born February 19, 1880, Baltimore, Md. (Cornell Univ., C. E., 1901)—1901 Sanitary engineering work in New York and Chicago: 1902-1906 member of firm of Williams and Whitman; conducted sanitary engineering work in New York, Connecticut, Massachusetts, New Jersey, Pennsylvania, Maryland, Tennessee, Ohio, and Texas: 1906 Div. Engr., Baltimore Sewerage Commission, in charge of Sewerage Experiment Station, Materials Testing Laboratory, and design and construction of sewage disposal works for Baltimore: 1911 Chf. Engr. and Pres., Water Board of Baltimore; operation and maintenance of water system; design and construction of improvements and extensions costing $5 000 000: 1914 consulting practice on water supply, sewerage systems, bridges and buildings: 1916 Civilian Asst. to Constr. Officer, Constr. Div., U. S. Army and, later, Major, Q. M. C., in charge of utilities, Camp Meade, Md.: 1919 investigation of municipal and housing conditions in Poland, at invitation of Polish National Commission: recently appointed to Public Service Commission of Maryland.

George Harrison Fenkell

(Candidate for Director, District No. 7)

Born February 4, 1873, at Cagrin Falls, Ohio—1891 Axeman and Rodman, Construction, Akron & Chi. Junction Ry., Ohio; Chainman for County Surv., Ionia County, Michigan: 1891-1892 Student at Univ. of Michigan: 1892-1893 Instrumentman and Asst. Res. Engr., location and construction, Wilkes-Barre & East. Ry. Pennsylvania: 1894 Draftsman, Detroit Water-Works: 1894-1895 Masonry and Pile Insp. and Instrumentman, location and construction, Fort Plain & Richfield Springs Ry., New York: 1895 Chainman, maintenance of street railways, Cleveland, Ohio: 1896 Chainman and Instrumentman, location, Cleveland & Lorain Elec. Ry.; Instrumentman, paved road construction, County Road Commrs., Cuyahoga County, Ohio: 1896-1902 Draftsman and Chf. Draftsman, Detroit Water-Works: 1902-1907 Civ. Engr. to Commrs. of Water-Works, Erie, Pa.: 1908-1913 Civ. Engr. to Board of Water Commissioners, Detroit: 1913-1918 Commr. of Public Works, Detroit, in charge of construction and maintenance of all pavements, sewers, docks, bridges, municipal asphalt plant, street and alley cleaning, refuse disposal, garbage collection, and Sewerage Pumping Station: 1918 to date Supt. and Gen. Mgr., Dept. of Water Supply, Detroit.

Ralph Norman Begien

(Candidate for Director, District No. 9)

Born March 15, 1875, Boston, Mass. (Two years at Harvard Univ.)—1897-1900 Instrumentman, Draftsman, and Junior Asst. Engr., U. S. Nicaragua Canal Commission and Isthmian Canal Commission on Surveys for Canal across Nicaragua: 1900 Asst. Engr. on Bridges and Location, Guayaquil & Quito R. R., Ecuador, in charge of Corps: 1901 Mathematician for U. S. Government in charge of computations in Surveyor General's Office, under bond: 1902 to date Baltimore & Ohio Railroad as follows: 1902-1907 Asst. Engr., Construction Dept., in charge of corps on surveys, trunk line improvements; 1907-1908 Asst. Engr., Headquarters Office, on special investigations (Engineering); 1908-1909 Div. Engr., Philadelphia Div., in charge of maintenance (Division); 1909-1910 Asst. Engr., Maintenance of Way, in charge of maintenance (Main Line System); 1910 Asst. to Chf. Engr., in charge of engineering under Chief Engineer; 1910-1911 Asst. to Gen. Mgr., in charge of operating efficiency work; 1912 Asst. Gen. Supt., in charge of operating and maintaining, Main Line System; 1913-1916 Gen. Supt., B. & O. S. W. R. R., in general charge of operation, engineering, maintenance of way and equipment; 1916-1917 Chf. Engr., B. & O. System, and C. H. & D. Ry., under Receivers; 1917 Gen. Mgr., Eastern Lines, B. & O. R. R., in general charge of operation, engineering, maintenance of way and equipment; 1918 Asst. to Federal Mgr., in charge of engineering and operation B. & O. Lines East; West. Md. R. R.; Cumberland Val. R. R.; Cumberland & Penn. R. R.; Coal & Coke Ry.; Wheeling Terminal R. R.; 1919 Federal Mgr., U. S. Railroad Administration, in general charge of operation, maintenance of way, equipment, engineering and traffic, B. & O. West. Lines, Dayton & Union R. R., Dayton Union R. R.: 1920 to date Gen. Mgr., B. & O. R. R., Lines West, in general charge of maintenance of way, maintenance of equipment, engineering and operation.

George Cotner Mason

(Candidate for Director, District No. 12)

Born May 4th, 1871, New York, N. Y. (New York Univ., B. S., 1892; C. E., 1893; M. S., 1894)—1892-1904 Eng. Faculty, New York University, and in private practice in New York City: 1904 to date Vice-Pres. and Chf. Engr., Hurley-Mason Company, Portland, Ore., and Tacoma, Wash., designing and construction work in the Northwest, work includes buildings, water-works, sewage plants, bridges, roads, elevators, hydro-electric plant, and paper mills.

ACTIVITIES OF LOCAL SECTIONS*

Meeting of San Francisco Section

A regular meeting of the San Francisco Section was held at the Engineers' Club, on June 20th, 1922; President Thomas H. Means in the chair; H. D. Dewell, Secretary; and present, also, 62 members and guests.

The meeting was preceded by a dinner, the guests at which were members of the Consulting Board to the Water Resources Investigation of the State Department of Public Works, Division of Irrigation and Engineering.

President Means announced the death of William Cushing Edes, M. Am. Soc. C. E., a member of the Section, and Messrs. Oakley, Benfield, and Newman were appointed a committee to draft a suitable memoir of Mr. Edes.

As Chairman of the Committee on Society Welfare, Mr. E. T. Thurston referred to the vacancy in the California Railroad Commission and moved that the Section ask the Governor to appoint an engineer on the Commission. The motion was seconded and, after discussion by Messrs. White, Marx, and O'Shaughnessy, was carried.

Mr. Thurston reported progress for the Committee on Standard Contract Forms, and asked for permission to forward his report to the Secretary of the Society. He also suggested a special meeting of the Section to consider the report when the Committee had concluded its work.

Mr. F. H. Fowler, Chairman of the Excursion Committee, asked for suggestions for suitable excursions.

The Publicity Committee, through Mr. A. T. Parsons, Chairman, reported that it was securing notices of the activities of the Section in the local press.

President Means presented the suggestion of President Freeman of the Society relative to a "dignified campaign for membership" in the Society by the various Local Sections, and suggested that individual members of the Section take up the matter among the engineers of their acquaintance.

Motion pictures of the Spring Meeting of the Society at Dayton, Ohio, April 5th-7th, 1922, made by the National Cash Register Company of Dayton, were shown, as well as a scenic film taken in the Yosemite Valley.

The topic of the evening was "Water Resources Investigation, Division of Engineering and Investigation, State Department of Public Works". The discussion was opened by Mr. J. C. Forkner, of Fresno, Calif., Chairman of the Consulting Board, who was followed by Mr. J. J. Haley who, in the absence of Paul Bailey, Assoc. M. Am. Soc. C. E., of the Division of Engineering and Irrigation, outlined briefly the scope of the investigation. Discussion on the subject was participated in by Messrs. C. D. Marx, C. H. Lee, Thomas H. Means, J. D. Galloway, R. B. Marshall, A. E. Chandler, E. B. Bumsted, and Attorney General Webb.

Meetings of Los Angeles Section

The regular meeting of the Los Angeles Section was called to order at 7:45 P. M., on July 5th, 1922, at the City Club; President Ralph J. Reed in

* For list of Local Sections, Officers, etc., see 1922 Year Book, p. 41, and also p. 590.

the chair; F. G. Dessery, Secretary; and present, also, 34 members and 18 guests, among the latter being the officers of the various Local Technical Societies.

The topic of the evening, "The Purpose of the Joint Engineering and Research Organizations", was presented by Alfred D. Flinn, M. Am. Soc. C. E., Secretary of the United Engineering Society and Engineering Foundation, and Chairman of the Division of Engineering of National Research Council. Mr. Flinn recited the history of these organizations and presented in detail the work accomplished to date, giving an outline of future problems to be investigated, including examples of the kind of work being undertaken by Engineering Foundation and the Division of Engineering of the National Research Council.

Discussion of the subject was participated in by Messrs. Reed, Schmidt, LaRue, Code, Pratt, Howell and Dessery.

At the conclusion of his address, Mr. Flinn was extended a vote of thanks by the Section.

Meeting of August 9th, 1922.

The regular monthly meeting of the Los Angeles Section was held on August 9th, 1922, at the City Club; President Ralph J. Reed in the chair; Homer J. Sharp, acting as Secretary; and present, also, 42 members and 9 guests.

President Reed announced the death of Archie Lee Harris, Assoc. M. Am. Soc. C. E., a member of the Section. On motion, duly seconded, the President was instructed to appoint a committee to draw up resolutions of sympathy and to prepare a memoir of the life of Mr. Harris.

The speaker of the evening, H. W. Dennis, M. Am. Soc. C. E., Construction Engineer of the Southern California Edison Company, was introduced by President Reed. Mr. Dennis addressed the meeting on "The Big Creek Construction Program of the Southern California Edison Company", pointing out the magnitude of the Company's power development under the Big Creek Construction Program. The address was illustrated with motion pictures of the project.

Fall Meeting of Texas Section

The program for the Fall Meeting of the Texas Section which is to be held on October 20th and 21st, 1922, at San Antonio, Tex., includes papers by B. S. Wathen, M. Am. Soc. C. E., on "Early History of Railroad Engineering in Texas"; F. E. Giesecke, M. Am. Soc. C. E., on "Strength of Concrete"; E. P. Arneson, Assoc. M. Am. Soc. C. E., on "Early Irrigation Systems in Texas"; Arthur A. Stiles, M. Am. Soc. C. E., on "Levee Building in Texas"; E. N. Noyes, M. Am. Soc. C. E., on "Report on Governor's Engineering Conference"; G. G. Wickline, M. Am. Soc. C. E., on "Bridge Problems of Texas Highway Department"; and by C. J. Howard, M. Am. Soc. C. E., on "Water System of Corpus Christi".

ANNOUNCEMENTS

The Reading Room of the Society is open from 9 A. M. to 6 P. M., and from 7 P. M. to 10 P. M., every day, except Sundays, New Year's Day, Washington's Birthday, Memorial Day, Fourth of July, Labor Day, Thanksgiving Day, and Christmas Day; during July and August, it is closed at 6 P. M.

FUTURE MEETINGS

October 4th, 1922.—8 P. M.—A regular monthly business meeting will be held, at which two papers will be presented for discussion, as follows: "Experiments with Models of the Gilboa Dam and Spillway", by R. W. Gausmann and C. M. Madden, Associate Members, Am. Soc. C. E.; and "The Engineering Geology of the Catskill Water Supply", by Charles P. Berkey, Esq., and James F. Sanborn, M. Am. Soc. C. E.

These papers were printed in *Proceedings* for September, 1922.

FALL MEETING OF THE SOCIETY AT SAN FRANCISCO, CALIF., OCTOBER 4th-8th, 1922

October 4th, 1922.—9 A. M. and 8 P. M.—Symposium on The Water Power Problem.

October 4th.—2 P. M.—Local excursions.

October 5th.—9 A. M.—Continuation of Symposium on The Water Power Problem.

October 5th.—2 P. M.—Local excursions.

October 5th.—6:30 P. M.—Dinner and Smoker.

October 6th to 8th.—Excursion to Don Pedro Dam, Hetch Hetchy, and Yosemite Valley.

All excursions and social functions are in the hands of the following Local Committee on Arrangements:

A. H. Markwart, *Chairman,*

H. D. Dewell, Thomas H. Means,
Ely C. Hutchinson, F. H. Tibbetts.

A circular containing information as to the general program, transportation, hotel rates, etc., has been issued to the membership.

LIST OF OFFICIAL NOMINEES FOR THE OFFICES TO BE FILLED AT THE ANNUAL ELECTION, JANUARY 17th, 1923.

For President, to serve one year:

CHARLES F. LOWETH, Chicago, Ill.

For Vice-Presidents, to serve two years:

GEORGE S. DAVISON, Pittsburgh, Pa.
ANSON MARSTON, Ames, Iowa.

For Directors, to serve four years:

GLENN D. HOLMES, Syracuse, N. Y. .... District No. 3
E. B. WHITMAN, Baltimore, Md. .... District No. 5
GEORGE H. FENKELL, Detroit, Mich. .... District No. 7
R. N. BEGIEN, Cincinnati, Ohio .... District No. 9
GEORGE C. MASON, Portland, Ore. .... District No. 12

The vacancy caused by the death of the Official Nominee for District No. 8, will be filled by the Board of Direction at the Fall Meeting at San Francisco, Calif.

SEARCHES IN THE LIBRARY

As the Library of the American Society of Civil Engineers has been merged in the Engineering Societies Library, requests for searches, copies, translations, etc., should be addressed to the Director, Engineering Societies Library, 29 West 39th Street, New York City, who will gladly give information concerning the charges for the various kinds of service. A more comprehensive statement in regard to this matter will be found on page 26 of the Year Book for 1922.

NEW LOCAL SECTIONS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

The Constitutions of the following Local Sections have been approved by the Board of Direction since the list was prepared for the 1922 Year Book, pp. 41 *et seq.:*

Dayton Section (Constitution Approved by Board, 1922).

Charles H. Paul, President; K. C. Grant, Secretary-Treasurer, Winters Bank Building, Dayton, Ohio.

Lehigh Valley Section (Constitution Approved by Board, 1922).

George H. Blakeley, President; M. O. Fuller, Secretary-Treasurer, 732 Avenue H, Bethlehem, Pa.

Sacramento Section (Constitution Approved by Board, 1922).

Albert Givan, President; Joseph W. Gross, Secretary, Forum Building, Sacramento, Calif.

Toledo Section (Constitution Approved by Board, 1922).

M. J. Riggs, President; George N. Schoonmaker, Secretary-Treasurer, 716 Stickney Avenue, Toledo, Ohio.

Virginia Section (Constitution Approved by Board, 1922).

J. C. Carpenter, President; James F. MacTier, Secretary-Treasurer, 1312 Maple Avenue, Roanoke, Va.

NEW STUDENT CHAPTERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS *

The following Student Chapters have been authorized by the Board of Direction since the list was prepared for the 1922 Year Book, pp. 46 *et seq.*:

Clemson Agricultural and Mechanical College of South Carolina.

J. H. Baumann, President; W. J. Stribling, Secretary, Clemson Agricultural and Mechanical College of South Carolina, Clemson College, S. C.

Georgia School of Technology.

F. H. Harrison, President; C. M. Kennedy, Jr., Secretary, 91 West North Avenue, Atlanta, Ga.

Lehigh University.

John N. Marshall, President; George R. Swinton, Secretary, Lehigh University, Bethlehem, Pa.

North Carolina State College of Agriculture and Engineering.

H. I. Ivey, Secretary, North Carolina State College, Raleigh, N. C.

Norwich University.

J. H. Kane, President; Allen J. Hamilton, Secretary, Norwich University, Northfield, Vt.

Stadia Club (University of Oklahoma).

Lester W. Ellis, President; Edward W. Mars, Secretary, University of Oklahoma, 229 W. Buffy, Norman, Okla.

University of Virginia.

T. B. Kiener, Secretary, University of Virginia, University, Va.

Worcester Polytechnic Institute.

Carl F. Meyer, President; Albert P. Hayden, Secretary, Worcester Polytechnic Institute, Worcester, Mass.

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* By a recent ruling of the Board of Direction, the minimum membership of a Student Chapter has been fixed at 12 instead of 20.

MEMBERSHIP

(From August 9th to September 5th, 1922)

ADDITIONS

MEMBERS

		Date of Membership.
ALLEN, HAROLD DAYTON. 361 Clifton Ave., Newark, N. J.	Jun. Assoc. M. M.	April 30, 1907 Dec. 6, 1910 Aug. 28, 1922
BARNES, HOWARD PARKER. Div. Engr., Board of Water Supply, City of New York, Croton-on-Hudson, N. Y.		Aug. 28, 1922
BERGEN, GEORGE THOMAS. Engr., Day & Zimmermann, Inc., 611 Chestnut St. (Res., 6111 Washington Ave.), Philadelphia, Pa.		Aug. 28, 1922
CARSON, HARRY YOUNG. Research Engr., Am. Cast Iron Pipe Co., Birmingham, Ala.	Jun. Assoc. M. M.	Mar. 14, 1916 Oct. 14, 1919 Aug. 28, 1922
FINCH, ROYAL GEORGE. Deputy State Engr., State Engr.'s Office, Albany, N. Y.		Aug. 28, 1922
FISHER, LAWRENCE MACHEMER. Associate San. Engr., U. S. Public Health Service, 1246 Main St. (Res. 716 Queen St.), Columbia, S. C.	Assoc. M. M.	April 16, 1918 June 20, 1922
GALLAGHER, HERBERT MORGAN. Gen. Mgr., The Port Utilities Comm., Charleston, S. C.	Assoc. M. M.	June 16, 1919 Aug. 28, 1922
MATHER, RICHARD. Dist. Engr., Constr., B. & O. R. R., 1310 B. & O. Bldg., Baltimore, Md.		Aug. 28, 1922
MATTHEWS, IRVING ELLSWORTH. Engr., Water-Works, 68 Avondale Park, Rochester, N. Y.		Aug. 28, 1922
MOORE, ROY SAXTON. Asst. Engr., New York and New Jersey Bridge and Tunnel Commissions, New York City (Res., 81 Columbia Heights, Brooklyn, N. Y.)		June 19, 1922
NICHOLS, CHARLES ELIOT. Engr. with Stone & Webster, Inc., 57 Hancock St., Auburndale, Mass.		Aug. 28, 1922
PARKER, JAMES EDWIN. Asst. Engr., Alabama Power Co., Brown-Marx Bldg., Birmingham, Ala.	Assoc. M. M.	Oct. 1, 1913 Aug. 28, 1922
RITCHEY, JESSE STEELE. Asst. and Dist. Engr., Pennsylvania State Highway Dept., Wellsboro, Pa.	Assoc. M. M.	Aug. 31, 1915 Aug. 28, 1922
SCHLESINGER, GEORGE FUERLE. Cons. Engr., Ohio Contrs. Assoc., 3028 North High St., Columbus, Ohio	Assoc. M. M.	Aug. 31, 1915 Aug. 28, 1922
SHEA, WILLIAM JAMES. Engr., Board of Economics and Eng., 60 Broadway, New York City (Res., 601 Ocean Ave., Brooklyn, N. Y.)	Assoc. M. M.	May 12, 1919 Aug. 28, 1922
THOMPSON, WILLIAM GEORGE BOLAND. Cons. Highway Engr., 1104 Greenwood Ave., Trenton, N. J.	Assoc. M. M.	Feb. 4, 1914 Aug. 28, 1922
WEBB, ALEXANDER RAFFEN. Prof., Civ. Eng., Univ. of the Philippines, Manila, Philippine Islands		May 8, 1922

ASSOCIATE MEMBERS

BAWDEN, ALBERT JOHN. Engr., Drainage Ditches, St. Louis County, 504 Court House, Duluth, Minn.		June 19, 1922

ASSOCIATE MEMBERS—(*Continued*) Date of Membership.

BERTRAND, JOHN BAPTIST. Office Engr. and Supt. of Constr., Allied Contractors, Inc., 1611 Evans St., Omaha, Nebr.......... May 8, 1922

CARIGAN, WILLIAM EVERETT. Res. Engr., Federal Projects, Nos. 10 and 7, LaRue and Hart Counties, Hodgenville, Ky...... Aug. 28, 1922

CARROLL, CHARLES CLAUDE. Engr.-Contr. (Williamson, Carroll & Saunders), 510 National Bank Bldg., Charlottesville, Va.... June 19, 1922

COGSWELL, ROBERT COMAN. Secy., The F. K. Vaughn Bldg. Co., Hamilton, Ohio .... Aug. 28, 1922

DINNEY, HENRY CHARLES. Engr. and Builder (Dinney, Newgarden Co., Inc.), 17 West 42d St. (Res., 1124 Woodycrest Ave.), New York City.......................... Aug. 28, 1922

DONNELLY, CHARLES EDWARD. Engr., City Plan Comm., City Hall, Kansas City, Mo.......................... Aug. 28, 1922

ERISMAN, CHARLES WESLEY. Civ. and Highway Engr., 404 Agricultural Trust Bldg., Lancaster, Pa.......................... Aug. 28, 1922

FELCH, PARKE DE CAMP. 37 West 37th St., New York City (Res., 176 North 5th St., Newark, N. J.).......................... June 19, 1922

GALE, LLOYD ENNIS. Mgr., The Hankow Branch, Am. Trading Co., Hankow, China .... June 19, 1922

GINSBURG, WILLIAM. Chf. Engr., Ettinger Contr. Co., 44 Court St. (Res., 1246 President St.), Brooklyn, N. Y.......... Aug. 28, 1922

HARRIS, CLINTON LEE. Associate Prof., Architectural Eng., Pennsylvania State Coll., 500 Pugh St., State College, Pa....... Aug. 28, 1922

JACCARD, EUGENE SAMUEL. Asst. to R. J. Weir, Box 1347, Fresno, Calif. .... May 8, 1922

KEAGY, ARTHUR DAVID. Asst. Engr., The J. N. Chester Engrs., 54 Jones St., Crafton Br., Pittsburgh, Pa.......................... Aug. 28, 1922

KEITH, GERALD MARCY. Shop Insp., Frederic de P. Hone & Co., 13 Park Row, New York City (Res., 1815 Ditmas Ave., Brooklyn, N. Y.).......... Jun. Sept. 11, 1917; Assoc. M. June 19, 1922

KETTER, E. F. Chf. Draftsman, United States Coal & Coke Co., Box 385, Gary, W. Va.......................... Aug. 28, 1922

LEVEQUE, LESLIE LOU. Pres., The L. L. LeVeque Co., 1518 Clifton Ave., Columbus, Ohio.......................... Aug. 28, 1922

MANNING, JOHN JOSEPH. Lieut., C. E. C., U. S. N., Navy Supply Depot, 29th St. and 3d Ave., South Brooklyn (Res., 217 East 16th St.), Brooklyn, N. Y.......................... Aug. 28, 1922

MORGAN, RAY DEARBORN. Supt., Water and Sewer Dept., City of Mexia, Box 586, Mexia, Tex.......................... June 19, 1922

MORITZ, CHARLES JAMES. Pres. and Gen. Mgr., C. J. Moritz, Inc., Effingham, Ill. .... May 8, 1922

NEEDLES, ENOCH RAY. Asst. Engr., Harrington, Howard & Ash, 459 Colonial Rd., Roselle Park, N. J.......................... Aug. 28, 1922

PARMELEE, LOUIS RAY. Cons. Engr. to City of Helena, Box 66, Helena, Ark. .... Aug. 28, 1922

ROSENBLUM, NATHAN ALFRED. Pres., Enayar Constr. Co.; Pres., Romasch Constr. Co.; and Pres., N. A. R. Constr. Co., Palo Alto Ave., Hollis, N. Y.......................... Aug. 28, 1922

ASSOCIATE MEMBERS—(*Continued*)

		Date of Membership.
RUSSELL, WILLIAM HEPBOURNE. Dist. Mgr., Hugh J. Baker Co., 613 Dayton Savings and Trust Bldg., Dayton, Ohio	Jun. Assoc. M.	Nov. 27, 1917 Aug. 28, 1922
SCHROEDER, ERICH GEORGE. (Erich G. Schroeder Co.), 405 Broadway (Res., 1132½ Nineteenth St.), Milwaukee, Wis.		Aug. 28, 1922
STEIN, GEORGE JAMES. With Commerce Min. & Royalty Co., Box 397, Miami, Okla.		April 3, 1922
TAPMAN, SAMUEL FLETCHER. Pres., William W. Beers Co., 15 Park Row, New York City		May 8, 1922
ULLOM, CLAUDE WILLCOX. Insp. with Miami Conservancy Dist., Dayton, Ohio		Aug. 28, 1922

AFFILIATES

TAYLOR, CALEB MARSHALL. Supt., Port Reading Creosoting Plant, Port Reading (Res., 80 Hillside Rd., Elizabeth), N. J.	Aug. 28, 1922

JUNIORS

BARTLETT, CHARLES HENRY. 1447 East 66th Pl., Chicago, Ill.	June 19, 1922
CLARK, CLAIR LOUIS. Care, Blair Home Co., 49 Central Trust Bldg., Altoona, Pa.	Aug. 28, 1922
DOUGLAS, DAMON GREENLEAF. Asst. Supt. with Turner Constr. Co., 12 North Orange Ave., Orlando, Fla.	Aug. 28, 1922
HARKNESS, JOHN COUSTY. Sales Engr., The Consolidated Expanded Metal Cos., Braddock, Pa.	Aug. 28, 1922
HOELSCHER, LEONARD WILLIAM. 3431 Crittenden St., St. Louis, Mo.	Aug. 28, 1922
JACOT, HARRY LOUIS, JR. Care, State Highway Dept., Binghamton, N. Y.	June 19, 1922
LUCHINGER. Hydr. Engr., 24 Elm St., Potsdam, N. Y.	Aug. 28, 1922
RAAB, NORMAN CECIL. Junior Hydr. Engr., State Dept. of Public Works, Sacramento, Calif.	June 19, 1922
THOMPSON, JOHN STANLEY. Engr., The Arundel Corporation, 1726 Tribune Bldg., New York City (Res., 24 South Portland Ave., Brooklyn, N. Y.)	Aug. 28, 1922
UCHIMURA, SABRO. Care, Stone & Webster Co., Inc., Boston, Mass.	June 19, 1922

DEATHS

DEYO, SOLOMON LEFEVRE. Elected Member, June 6th, 1888; died August 19th, 1922.

DOUGLASS, ANTHONY CHILEON. Elected Affiliate, April 30th, 1895; died July 1st, 1922.

DRAKE, WILLIAM ABIAL. Elected Member, December 5th, 1883; died August 19th, 1922.

KONDO, TORAGORO. Elected Junior, October 3d, 1888; Member, June 5, 1901; died July 17th, 1922.

MERIWETHER, DAVID, JR. Elected Member, November 9th, 1920; died June 21st, 1922.

OLDS, CLARK. Elected Associate Member, March 1st, 1899; died August 16th, 1922.

SANBORN, MORTON FRANKLIN. Elected Associate Member, March 1st, 1910; Member, January 18th, 1916; died July 30th, 1922.

WATSON, WINSLOW BARNES. Elected Associate Member, September 12th, 1916; died August 6th, 1922.

Total Membership of the Society, September 5th, 1922

Members	4 607	
Associate Members	5 271	
Corporate Members		9 878
Honorary Members		10
Juniors		460
Affiliates		169
Fellows		10
Total		10 527

ENGINEERING SOCIETIES EMPLOYMENT SERVICE

An Engineering Societies Service Bureau was established December 1st, 1918, as an activity of Engineering Council. It was managed by a board made up of the Secretaries of the four Founder Societies, and funds for its maintenance were provided by these Societies. On January 1st, 1921, this Bureau was taken over by The Federated American Engineering Societies and was known as the Employment Service of that organization. Recently, the management of the Service has been taken over by the Founder Societies. A weekly Employment Bulletin, listing the positions available, may be seen at the office of any Secretary of a Local Section. Members of the American Society of Civil Engineers who desire to register should apply for further information, registration forms, etc., to Walter V. Brown, Manager, Engineering Societies Building, 29 West 39th Street, New York City. In order to be included in the list published in *Proceedings*, copy must be received on or before the first of each month. All communications should be addressed to Mr. Brown.

EMPLOYMENT BULLETIN

POSITIONS AVAILABLE

ARCHITECTURAL DRAFTSMAN experienced on school houses. Application in person. Location, New York City. V–2047.

STRUCTURAL STEEL DETAILERS AND CHECKERS (5). Must be experienced men. Application in person. Location, New York City. V–2054.

SALES ENGINEERS (3) to possess qualifications requisite to apply gas-fired steam boilers in industries and also for house heating; one for application of gas-fired appliances for heat treatment of metals; and one to possess qualifications for application of gas to gas-burning equipment to large bake-ovens. Application by letter. Location, New York. V–2110.

STRUCTURAL STEEL DRAFTSMAN (1 or 2) on design and checking in connection with architectural plans. Must be experienced. From 6 to 8 weeks' work. Application in person. Location, New York City. V–2163.

CIVIL ENGINEERS (3) experienced on highway construction to act as sales promotion experts among State Commissioners, engineers, and contractors. Application by letter. Salary not stated. Location, Ohio. V–2180.

CONSTRUCTION SUPERINTENDENT on reinforced concrete manufacturing building or wood frame office buildings. Three or four years' experience on construction work, in charge of men. Application by letter. Salary not stated. Location, Pa. V–2187.

ARCHITECTURAL DRAFTSMAN for residential and alteration work. Man familiar with New York building rules and having from 2 to 3 years' experience. Application in person. Location, New York. V–2190.

CHEMICAL ENGINEER OR PHYSICIST for lime research work. Application by letter. Salary not stated. Location not stated. V–2198.

HEAD DRAFTSMAN for architect's office. Application by letter. Salary not stated. Location, Arkansas. V–2210.

JUNIOR DRAFTSMAN for architect's office. Location, Little Rock, Ark. V–2211.

TIME STUDY ENGINEER with about 5 years' experience. Duties will be on construction, loading, and other labor problems. Application by letter stating age, experience, etc. Salary not stated. Location, New York City. V–2214.

SALES ENGINEER, experienced with air compressors and pneumatic tools, to act as Department Manager. Application in person. Salary not stated. Location, New York City. V–2227.

STRUCTURAL DRAFTSMAN, 2 years' experience. Temporary until Civil Service examination is taken and if passed, position will be permanent. Application in person. Location, New York City. V–2236.

SALES ENGINEERS familiar with the marketing of building materials with especial reference to building specialties. Application by letter. Salary not stated. Location, New York City. V–2252.

CHIEF DRAFTSMAN on chemical plant layout, who has also had experience on maintenance work. Application by letter. Salary not stated. Location, New York. V–2253.

EXPERIENCED ESTIMATOR, thoroughly posted on reinforced concrete and general building work. Only those having had at least 2 years' experience with one of the large construction companies will be considered. Application by letter only. Location, New York City. V–2258.

ENGINEER experienced in making investigations and surveys for water power development. Application in person. Salary not stated. Location, Northern Ontario, Headquarters, New York City. V–2260.

ASSISTANT CONSTRUCTION SUPERINTENDENT, Civil Engineer, with working knowledge of Spanish. Experience in outside construction of piers, warehouses; some design; single man preferred. No expense account, but traveling expense to and from job will be paid. Application in person, New York City. Location, Cuba. V–2264.

DRAFTSMAN for building construction on schools and churches. Application by letter stating age, education, and experience. Only engineers with this experience considered. Location, Pa. V–2266.

INSTRUCTOR in general engineering drawing, including descriptive geometry. Only graduates of recognized technical schools considered. Teaching experience desirable, but not essential. One or two years of practical engineering experience necessary. Must have good personality, be enthusiastic, and suited by aptitude to teaching work. Application by letter. Location, Illinois. V–2276.

ENGINEER to organize and take charge of district promotional and educational work on use of lime in building, agriculture, and chemistry. Work will be field work. Must have business experience in organization, sales, and executive capacities, initiative, adaptability, common sense, perseverance, good address, and ability to co-operate. Application by letter. District headquarters, St. Louis, Mo. National headquarters, Washington, D. C. V–2278.

REFRIGERATING SALES ENGINEER. Excellent opportunity for thoroughly experienced refrigerating engineer to travel in Western territory for old reliable manufacturers. Only those who can point to a successful sales record need apply. Application by letter, giving qualifications. Salary not stated. Location, Omaha, Nebr. V–2283.

MAN experienced in teaching in manual schools. Two years' contract. Must be college man. To teach trades to children in Russia and Asia Minor. Application in person. Headquarters, New York City. V–2287.

ASSISTANT SUPERINTENDENT for Whiting plant, manufacturing marble. Plant runs day and night. Must be good executive, experience in handling men, and familiar with similar machinery. Application by letter. Location, Vermont. V–2297.

SALES MANAGER on building material for general office follow up. Good appearance. Application in person by appointment. Salary not stated. Location, New York City. V–2298.

YOUNG ENGINEER; Electrical or Mechanical, experienced in the use and application of auxiliary for high-pressure, modern, steam power plants. Ability to write advertising copy and prepare technical articles for press essential. Company manufactures electrical valve-control equipment used exclusively on steam lines in large power stations and also complete line of valve control apparatus for water-works and power stations. Will also act as research engineer for new fields for control and must possess sufficient business and engineering knowledge to carry on work without supervision. Prefer married man, age not more than 35 or 40, already in a similar position. Application by letter. Salary not stated. Location, Conn. V–2302.

FIRST-CLASS DESIGNING ENGINEER AND DRAFTSMAN. Must be technically trained and have had some experience. Application by telegram, stating age, education, and experience. Location, Oklahoma. V–2303.

MECHANICAL DRAFTSMAN in power plant, boiler and industrial furnace work. Application by letter. Salary not stated. Location, New York City. V–2304.

SUPERINTENDENT of plant manufacturing radio apparatus. Electrical and mechanical knowledge and experience in this work. Age 28 to 40. Location, New York City. Application in person by appointment. V–2305.

ENGINEER capable of doing some editorial work for *Marine Review*. Some practical experience at sea, in shipyards, or preferably in office of well organized ship operating company desirable. Should have had at least 5 years' practical experience. Experience as technical journalist desirable, but not necessary. Ability to write absolutely essential. Must be familiar with American shipping. Application by letter. Location, Ohio. V–2308.

MECHANICAL ENGINEER with paper-pulp mill experience. Must be familiar with structural steel and reinforced concrete design. Permanent position for right man. Application by letter giving age, references, nationality, salary receiving and expected, in first letter. Location, North Carolina. V–2327.

HYDRAULIC ENGINEER experienced in hydraulic design, computations, and construction work. Single man preferred. Application by letter. Salary not stated. Location, West. V–2351.

TOPOGRAPHICAL DRAFTSMAN. Work will consist of taking field notes, making necessary calculation, plotting, and tracing. Transportation paid from port of sailing. Board about $30. per month. Should be single, or, if married, be willing to go without family. Application by letter. Salary, $175 per month. Location, Guatemala. V–2359.

MEN AVAILABLE

CIVIL ENGINEER, Assoc. M. Am. Soc. C. E.; age 36; married; desires position in engineering work or teaching mathematical or engineering subjects. Practical experience, ten years on Highway, Hydrographic, and Structural Engineering. Teaching since 1919. CE–354.

MUNICIPAL, PARTICULARLY WATER-WORKS, ENGINEER AND SUPERINTENDENT; age, over 50. More than 30 years in employ of large city, State, and U. S. Government, in responsible charge of construction and maintenance: Streets, sewer work, hydraulic computations, handling of

men, writing of engineering articles, fire protection, Court work, power plant supervision. Salary not less than $3 000. Northeastern States preferred. CE–355.

ENGINEER, M. Am. Soc. C. E.; Graduate M. I. T.; age 37; unmarried. Eight years' experience in design of dams, power-houses, headworks, etc., and in water-power studies. Desires responsible position on water-power investigations or designs. Immediately available. Personal interview solicited. CE–356.

STRUCTURAL ENGINEER, Assoc. M. Am. Soc. C. E.; college graduate; age 31; married. Ten years' experience; for past six years, and at present, employed with large industrial corporation in charge of construction of steel and reinforced concrete buildings including paper mill, chemical, office and warehouse buildings, supervising plans, specifications, designs, letting contracts, erection and equipment installation. Desires position with consulting engineer, or concern contemplating large expansion. Available on short notice. CE–357.

CIVIL ENGINEER, college graduate, is open for responsible executive position. Twenty years' practical experience in design and construction work of all kinds; thoroughly conversant with appraisal work, the preparation of reports and financial statements, and the analysis of general business conditions, in regard to engineering projects. Highest technical and business references. CE–358.

CIVIL ENGINEER; technical graduate; age 36; experienced on stream flow studies, design and construction of hydro-electric plants, plate, steel, and concrete pipe lines and surge tanks, timber, steel, and concrete structures; construction and works engineer on chemical plants manufacturing sulphuric and phosphoric acids, cyanamid, ammonium sulphate, and phosphate, beta-naphthol and dyes; in charge of construction, progress reports, and operating records for Nitrate Plant No. 2; New York State Professional Engineer license. New York City, New Jersey, or Eastern Pennsylvania. CE–359.

CIVIL ENGINEER, M. Am. Soc. C. E., university graduate; age 40; married. Seventeen years' varied experience; heavy railroad construction in earthwork and bridges; office engineer, in charge of extensive valuation for large utility property; extensive street and interurban railway experience. At present, Engineer, Maintenance of Way, with large utility property in executive position. Capable engineer executive. Location immaterial. Permanently located at present, but desires change. Interview solicited. CE–340.

MINUTES OF MEETINGS
OF THE SOCIETY

September 6th, 1922.—The meeting was called to order at 8:10 P. M.; President John R. Freeman in the chair; John H. Dunlap, Secretary; and present, also, 66 members and guests.

The minutes of the meeting of June 7th, 1922, and of the Annual Convention on June 21st, 1922, were approved as printed in *Proceedings* for August, 1922.

The Secretary announced the election of the following candidates on August 28th, 1922:

As Members

Howard Parker Barnes, Croton-on-Hudson, N. Y.
Jay Foster Beaman, Berkeley, Calif.
George Thomas Bergen, Philadelphia, Pa.
Clarence Henry Bowman, Casper, Wyo.
Alexander Brociner, New York City
William Elmhirst Duckering, Ames, Iowa
Royal George Finch, Albany, N. Y.
Charles Victor Rockwell Fullenwider, Wyoming, Ohio
Charles Edward Griggs, Tulsa, Okla.
Lewis Gladstone Hooper, New Orleans, La.
Eugene Christian Hultman, Boston, Mass.
John Derby Cornelius Mackey, Port Washington, N. Y.
Richard Mather, Baltimore, Md.
Irving Ellsworth Matthews, Rochester, N. Y.
James Henry Stewart Melville, New York City
Richard Henry Morris, Philadelphia, Pa.
O'Kelly William Myers, Brooklyn, N. Y.
Charles Eliot Nichols, Auburndale, Mass.
Robert Vance Orbison, South Pasadena, Calif.
Charlton Dascom Putnam, Dayton, Ohio
Winchester Englebert Reynolds, Kansas City, Mo.
Alfred Hummel Sauerbrun, Elizabeth, N. J.
Clifford Shoemaker, Washington, D. C.
Arthur Gregg Singer, Philadelphia, Pa.
Henry Atterbury Smith, New York City
Henry Vose Spurr, New York City
Wilbur M. Wilson, Urbana, Ill.

As Associate Members

William Drees Aiken, Mamaroneck, N. Y.
John Michael Allen, Newark, N. J.
Ray Parker Barber, Toleda, Ohio
Ronald Mackenzie Beck, Newark, N. J.
Harry French Blaney, Los Angeles, Calif.

Harrison Brand, Jr., Pasadena, Calif.
Francis Paul Canavan, Philadelphia, Pa.
William Everett Carigan, Hodgenville, Ky.
John Williams Cleland, Glendale, Calif.
Robert Coman Cogswell, Hamilton, Ohio
Jehangir Ruttonjee Colabawala, Mutunga, Bombay, India
Seaborn Jones Cunningham, Jefferson City, Mo.
Henry Charles Dinney, New York City
Charles Edward Donnelly, Kansas City, Mo.
Walter Dreyer, San Francisco, Calif.
Harry Englander, New York City
Charles Wesley Erisman, Lancaster, Pa.
Edmund Burke Feldman, Minneapolis, Minn.
Harry Edward Frech, St. Louis, Mo.
Bernard Miles Gallagher, Los Angeles, Calif.
William Ginsberg, Brooklyn, N. Y.
Charles Sailor Gleim, Westfield, N. J.
Herbert William Hanauer, Heliopolis, Egypt
Clinton Lee Harris, State College, Pa.
Daniel Storms Helmick, Minneapolis, Minn.
Lambertus Frederik Heuperman, Salem, Ore.
Chester Allen Hogentogler, Washington, D. C.
Joseph Edwin Hughes, Balboa Heights, Canal Zone, Panama
Arthur David Keagy, Pittsburgh, Pa.
Lester Josef Newman Keliher, Little Rock, Ark.
Charles Macdonald Kerr, New Orleans, La.
E. F. Ketter, Gary, W. Va.
Harold Leslie Layman, Lawrence, Kans.
Leslie Lou LeVeque, Columbus, Ohio
George Taylor Lloyd, Green Cove Springs, Fla.
James Lewis Lochridge, Wichita Falls, Tex.
David Livingstone MacBeath, San Francisco, Calif.
Edward Taylor McIlvain, Pittsburgh, Pa.
Clifford Thomas McIntyre, Highland Park, Mich.
James Gordon McKenzie, Galveston, Tex.
Arthur Sawyer Mahony, Clifton, N. J.
John Joseph Manning, Brooklyn, N. Y.
Arnold Matthew Meyer, New York City
Enoch Ray Needles, Roselle Park, N. J.
Samuel Eugene Neill, Birmingham, Ala.
George Henry Noble, Paterson, N. J.
William Henry Pahl, Lincoln, Nebr.
Louis Ray Parmelee, Helena, Ark.
Roderic Pearson, Ogden, Utah

Leroy Preston Raynor, Washington, D. C.
Charles Wallace Resmaw, Los Angeles, Calif.
Eugene Franklin Rice, Central Aguirre, Porto Rico
Henry Clay Riesbol, New York City
Nathan Alfred Rosenblum, Jamaica, N. Y.
Erich George Schroeder, Milwaukee, Wis.
Thomas Ray Shaver, Oak Park, Ill.
Herbert Chester Stevens, Caledonia, N. S., Canada
Gustave Adolph Strand, Oakland, Calif.
Claude Wilcox Ullom, Dayton, Ohio
Clarence Arthur Walkwitz, Chicago, Ill.
Wade Lowe Webster, Rogersville, Tenn.

As Affiliates

Caleb Marshall Taylor, Elizabeth, N. J.
Ralph Franklin Ware, Los Angeles, Calif.

As Juniors

Philip Rowland Roosegaarde Bisschop, Berkeley, Calif.
Richard Pearson Bryan, Ely, Nev.
Herbert Fuller Butler, New Rochelle, N. Y.
Joe Beaty Butler, Rolla, Mo.
Salvatore Cascio, Brooklyn, N. Y.
John Francis Casey, Jr., Pittsburgh, Pa.
Clair Louis Clark, Altoona, Pa.
Robert Wetmore Collins, Houston, Tex.
Philip Brooks Craighead, Pittsburgh, Pa.
Damon Greenleaf Douglas, Orlando, Fla.
Toros Haroutune Fermanian, Ayazma, Turkey
Gustav Arthur Goerger, Huntington, N. Y.
John Cousty Harkness, Braddock, Pa.
Leonard William Hoelscher, St. Louis, Mo.
Clarence Ramsey Kapp, Rushville, Nebr.
Abol Fazl Khan, Carroll, Iowa
Albert Luchinger, Potsdam, N. Y.
Jay Wheelock McCullough, Fruita, Colo.
Robert Louis Monroe, Trenton, N. J.
Raymond Anthony O'Hara, New York City
Harry Smith, Norfolk, Va.
Jeno Sterns, New York City
Robert Francis Anthony Studds, San Francisco, Calif
John Stanley Thompson, Brooklyn, N. Y.

The Secretary announced the transfer of the following candidates on August 28th, 1922:

From Associate Member to Member

Harold Dayton Allen, Newark, N. J.
George Whitney Bates, Lincoln, Nebr.
John Arthur Beemer, Yerington, Nev.
Joseph L. Burkholder, Denver, Colo.
Harry Young Carson, Birmingham, Ala.
Louis Rea Douglass, Trinidad, Colo.
Herlup Trolle Forchhammer, London, England
Herbert Morgan Gallagher, New Orleans, La.
Bernhard Faaborg Jakobsen, Fresno, Calif.
Elmer Earl Moots, Mount Vernon, Iowa
Charles Church More, Seattle, Wash.
James Edwin Parker, Birmingham, Ala.
Jesse Steele Ritchey, Wellsboro, Pa.
George Fuerle Schlesinger, Columbus, Ohio
William James Shea, Brooklyn, N. Y.
Russell Elstner Snowden, Kinston, N. C.
William George Boland Thompson, Trenton, N. J.
Oliver Julian Todd, Shanghai, China

From Junior to Associate Member

Warner Cotton Brockway, Lansing, Mich.
Joel Bean Cox, Paia, Maui, Hawaii
William Thomas Crowley, Lock Haven, Pa.
DeWitt Clinton Gross, Chicago, Ill.
Clarence Paulding Rhynus, Toledo, Ohio
William Hepbourne Russell, Dayton, Ohio

The following deaths were announced:

John Anderson Bensel (*Past-President*), of New York City, elected Junior, September 2d, 1885; Member, March 4th, 1891; died June 19th, 1922.

Robert Moore (*Past-President*), of St. Louis, Mo., elected Member, April 5th, 1876; died July 24th, 1922.

Archibald Stuart Baldwin, of Chicago, Ill., elected Member, December 6th, 1905; died June 26th, 1922.

Solomon LeFevre Deyo, of New York City, elected Member, June 6th, 1888; died August 19th, 1922.

William Abial Drake, of Prescott, Ariz., elected Member, December 5th, 1883; died August 19th, 1922.

William Cushing Edes, of San Rafael, Calif., elected Junior, September 1st, 1886; Member, November 4th, 1896; died May 25th, 1922.

George Russell Field, of Requa, Calif., elected Member, November 6th, 1907; died May 1st, 1922.

Albert Lincoln Johnson, of Buffalo, N. Y., elected Associate Member, September 2d, 1896; Member, December 4th, 1901; died July 21st, 1922.

Toragora Kondo, of Tokyo, Japan, elected Junior, October 3d, 1888; Member, June 5th, 1901; died July 17th, 1922.

David Meriwether, Jr., of Washington, D. C., elected Member, November 9th, 1920; died June 21st, 1922.

Cornelius Van Vorst Powers, of New York City, elected Member, March 1st, 1905; died June 18th, 1922.

James George Ross, of Memphis, Tenn., elected Member, May 28th, 1912; date of death unknown.

Morton Franklin Sanborn, of Pleasantville, N. Y., elected Associate Member, March 1st, 1910; Member, January 18th, 1916; died July 30th, 1922.

Sergei Nicolaevitch Sissoeff, of Petrograd, Russia, elected Member, March 13th, 1917; date of death unknown.

Luther Wagoner, of San Francisco, Calif., elected Member, May 2d, 1906; died July 1st, 1922.

Ralph Benjamin Allen, of Albany, N. Y., elected Associate Member, March 13th, 1917; died June 17th, 1922.

Harry Henry Frost, of Akron, Ohio, elected Associate Member, June 4th, 1913; died January 26th, 1922.

Archie Lee Harris, of Los Angeles, Calif., elected Associate Member, May 31st, 1910; died July 18th, 1922.

Gerardus Harrisson, of New York City, elected Associate Member, January 13th, 1919; died July 24th, 1922.

Arthur Francis Holland, of Milwaukee, Wis., elected Associate Member, October 14th, 1919; died June 22d, 1922.

Walter Lawrence Hull, of Orange, N. J., elected Associate Member, January 19th, 1920; died June 20th, 1922.

Lowell Gaynor Krigbaum, of San Francisco, Calif., elected Junior, November 4th, 1914; Associate Member, August 9th, 1920; died May, 1921.

Clark Olds, of Erie, Pa., elected Associate Member, March 1st, 1899; died August 16th, 1922.

John Earl Shoemaker, of Marion, Ill., elected Associate Member, June 6th, 1911; died June 22d, 1922.

Fred Charles Smith, of Cincinnati, Ohio, elected Associate Member, October 29th, 1912; died June 13th, 1922.

Winslow Barnes Watson, of Plattsburgh, N. Y., elected Associate Member, September 12th, 1916; died August 6th, 1922.

Anthony Chileon Douglass, of Niagara Falls, N. Y., elected Affiliate, April 30th, 1895; died July 1st, 1922.

A paper entitled "Locomotive Loadings for Railway Bridges" by D. B. Steinman, M. Am. Soc. C. E., was presented by the author who illustrated his remarks with lantern slides. The subject was discussed orally by Messrs. H. B. Seaman, Charles A. Mead, Charles Evan Fowler, C. F. Loweth, O. H. Ammann, H. C. Keith, and A. W. Buel, and written discussions by Messrs. C. D.

Purdon, Robert C. Strachan, Victor H. Cochrane, Albert Lucius, B. A. Worthington, G. H. Gilbert, J. A. L. Waddell, Gustav Lindenthal, R. A. Caughey, J. C. Ralston, J. C. Bland, J. M. Johnson, C. S. G. Rogers, E. A. Stone, Harold C. Bird, Almon H. Fuller, Carleton T. Bishop, Clyde W. MacCornack, and C. P. Disney, were announced by the Secretary.

Adjourned.

OF THE BOARD OF DIRECTION

This is an abstract of the notes of the Secretary and subject to approval by the Board of Direction at its next meeting.

August 28th, 1922.—The Board convened in regular meeting at 8:10 P. M., at the Headquarters of the Society; Vice-President A. M. Hunt in the chair; John H. Dunlap, Secretary; and present, also, Messrs. Curtis, Greene, Hogan, Holland, Humphrey, McConnell, Pegram, and Ridgway.

Ballots for membership were canvassed, resulting in the election of 27 Members, 61 Associate Members, 2 Affiliates, and 24 Juniors, and the transfer of 6 Juniors to the grade of Associate Member.

Eighteen Associate Members were transferred to the grade of Member.

A report from the Membership Committee was received and acted on.

Adjourned.

NEW BOOKS*

(From August 1st to August 31st, 1922)

The statements made in these notices are taken from the books themselves, and this Society is not responsible for them.

DONATIONS TO ENGINEERING SOCIETIES LIBRARY

STANDARD HANDBOOK FOR ELECTRICAL ENGINEERS.

Frank F. Fowler, Editor-in-Chief. Fifth Edition, Revised. N. Y. and Lond., McGraw-Hill Book Co., 1922. 2137 pp., diagrams, 7 x 4 in., fabrikoid. $6.00.

As the last edition of this popular handbook appeared seven years ago, its revision which takes account of the many new developments since that time, will be widely welcomed. No change has been made in the general arrangement and make-up, but each section has been thoroughly revised by the substitution of modern material and data for such as had become obsolete. Substantial changes have been made in almost every section, a few have been rewritten, and new material has been added to others.

L'UNION D'ÉLECTRICITÉ ET LA CENTRALE DE GENNEVILLIERS.

By Ernest Mercier. Paris, La Revue Industrielle, 1922. 48 pp., illus., pl., 12 x 9 in., paper.

The Union Française d'Electricité, formed in 1919, is a combination of the principal central stations serving Paris and its environs, organized to unify the systems of distribution in existence, to eliminate competition between its organizers, and to provide for the future in a rational way. This monograph describes the distributing system adopted and the generating stations acquired. The principal part of the book is devoted to the new power plant under construction at Gennevilliers, planned for a present output of 200 000 kw., with future enlargement to 320 000 kw. This station is described in detail, and many plans and illustrations are given.

LES APPLICATIONS ÉLÉMENTAIRES DES FONCTIONS HYPERBOLIQUES A LA SCIENCE

de l' Ingénieur Électricien. Par A. E. Kennelly. Paris, Gauthier-Villars et Cie., 1922. 153 pp., diagrams, 9 x 6 in., paper.

Dr. Kennelly spent the academic year 1921–22 as an Exchange Professor in France, where he delivered a course of lectures to universities and engineering schools on the applications of hyperbolic functions to electrical engineering problems. This monograph, based on these lectures, places before the French student, in abridged form, the material already published in English by the author.

MARINE POWER PLANT.

By Lawrence B. Chapman. N. Y. and Lond., McGraw-Hill Book Co., 1922. 320 pp., illus., diagrams, 9 x 6 in., cloth. $4.00.

The purpose of this book is to bring before the student the thermodynamics of the marine power plant, the types of machinery used for ship propulsion, and to give him a comprehensive idea of the layout and purposes of the auxiliary machinery. It is intended as a first book in marine engineering for students of naval architecture, marine engineering, and ship operation, but should prove useful also to sea-going engineers and shipowners.

PRODUCTION MILLING.

By Edward K. Hammond. N. Y., Industrial Press, Lond., Machinery Pub. Co., Ltd., 1921. 278 pp., illus., 9 x 6 in., cloth. $3.00.

The purpose of this book is to explain the application of some of the more efficient methods of operating milling machines in the production of duplicate parts in quantities. The methods discussed have been collected from many sources and have all been successfully used under shop conditions. A knowledge of milling machines is assumed.

PRINCIPLES OF INTERCHANGEABLE MANUFACTURING.

By Earle Buckingham. N. Y., Industrial Press; Lond., Machinery Pub. Co., Ltd., 1921. 254 pp., illus., diagrams, 9 x 6 in., cloth. $3.00.

In this treatise, the author first takes up the general principles involved in interchangeable manufacturing and then devotes a chapter to the definition of the terms used. The influence of interchangeable processes on machine design and the purpose of models are then

* Unless otherwise specified, books in this list have been donated by the publishers.

dealt with, followed by a detailed discussion of the dimensioning of drawings for use in interchangeable manufacturing. This is followed by an account of the principal elements that govern economical production, the equipment required, the gauge equipment, and the principles of inspection and testing. Special chapters treat manufacturing for selective assembly, small-quantity methods, and the service factor in interchangeable manufacturing.

MECHANICAL TESTING: VOL. I.

By R. G. Batson and J. H. Hyde. (Directly-Useful Technical Series.) N. Y., E. P. Dutton & Co., 1922. 413 pp., pl., illus., diagrams, 9 x 6 in., cloth. $9.00.

The object of this book is to place before the engineer, the manufacturer, and the student the conditions governing modern testing, the particulars of standard testing plant equipment and its limitations and the information necessary to apprize the results obtained at their true values. This volume is confined to materials of construction, metals, timber, stone, brick, concrete, limes, cements, and road materials

PRINCIPLES OF ORGANIC CHEMISTRY.

By James F. Norris. Second Edition. N. Y. and Lond., McGraw-Hill Book Co., 1922. 631 pp., 8 x 6 in., cloth. $3.00.

[illegible]ok for beginners in the subject, in which the fundamental principles of the science [illegible] emphasized and selected compounds of practical importance are described in some detail. This second edition takes account particularly of the recent developments in industrial organic chemistry and emphasizes the new industrial processes brought forward during the World War.

METALLOGRAPHY.

By Cecil H. Desch. Third Edition. Lond. and N. Y., Longmans, Green & Co., 1922. 440 pp., pl., diagrams, 8 x 5 in., cloth. $5.00.

In this work, Professor Desch presents an account of the physical and microscopical methods used in the study of metallic alloys, sets forth the conclusions that have been reached, and indicates the directions in which further research is desirable. The literature of the subject has been studied critically and an attempt made to evaluate the various investigations. For this edition, the text has been thoroughly revised and the important recent work added, the most important changes occurring in the chapters on the physical properties of alloys, on corrosion, and on the metallography of iron and steel.

IRON ORE:

Parts 3–5. Issued by Imperial Mineral Resources Bureau. Lond., H. M. Stationery Office, 1922. 9 x 6 in., boards.

In these volumes, the Imperial Mineral Resources Bureau of the British Empire presents a concise account of the iron ore industry in various lands, with special reference to present and prospective supplies of ore. Each account is prepared from the most authoritative sources, is accompanied by maps and statistics, and forms a convenient summary of information upon the subject.

PETROLEUM; WHERE AND HOW TO FIND IT.

By Anthony Blum. Chicago, Modern Mining Books Publishing Co.; Lond., D. Appleton & Co., 1922. 367 pp., port., 7 x 5 in., cloth.

The aim of this book, according to the author, is to present in non-technical language that information concerning the oil industry which is wanted by laymen interested in oil properties. The situation of the petroleum industry and its future prospects, and the methods of winning and marketing petroleum are described, and advice given to would-be investors. The author draws on an experience of more than thirty years in Western States, in mining metals and petroleum.

MEXICAN PETROLEUM.

N. Y., Pan American Petroleum & Transport Co., 1922. 300 pp., illus., map, ports., 8 x 5 in., fabrikoid.

The primary purpose of this publication is to furnish information about the development of the Pan American Petroleum and Transport Company and its chief subsidiaries. The history of the Company is related, and its oil lands in Mexico and California are described. A detailed account of its equipment for transporting oil by land and sea, its facilities for supplying steamers with fuel oil at American and British ports, and an account of its refineries, are given. A general chapter on the geographical distribution of petroleum and various tables complete the book.

INDUSTRIAL PHYSICS; MECHANICS.

By L. Raymond Smith. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. 226 pp., illus., diagrams, 8 x 5 in., cloth. $1.75.

The present trend in education has created a demand for textbooks in which the material presented is closely connected with the every-day life of the student. This volume is an attempt to meet this demand by providing an elementary, practical textbook on mechanics, suitable for use in high schools and vocational schools.

WORLD METRIC STANDARDIZATION.

Compiled by Aubrey Drury. San Francisco, World Metric Standardization Council, 1922. 524 pp., ports., 9 x 6 in., cloth. $5.00.

A comprehensive survey of the arguments advanced in favor of the adoption of the metric system in commerce. The testimony of proponents of the system has been collected from a wide range of sources and summarized in convenient form for consultation. A bibliography of more than fifty pages is included.

CHAIN STORES.

By Walter S. Hayward and Percival White. N. Y. and Lond., McGraw-Hill Book Co., 1922. 411 pp., illus., 8 x 6 in., cloth. $3.50.

This book sets forth the principles of the operation, organization, management, and control of chain stores, and is intended for the executive at headquarters, the branch manager, and his assistants. The authors hope that it will also prove stimulating to independent retailers and others interested in methods of distribution.

PLUMBING FIXTURE TRAPS.

By A. E. Hansen. N. Y., The Author, 1921. 83 pp., illus., 9 x 7 in., cloth. $2.00.

This book is a useful contribution to the discussion of the comparative merits of vented and unvented traps. The author reviews briefly the history of these fixtures, quotes from authorities and modern plumbing regulations, and presents tables showing the cities which permit unvented traps to be used and which do not. The tests of the Geco trap made in 1918 by the New York City Board of Standards and Appeals are described and criticized unfavorably. A series of tests by the author are described in detail. The author does not approve unvented traps.

DESIGN OF MASONRY STRUCTURES AND FOUNDATIONS.

By Clement C. Williams. N. Y. and Lond., McGraw-Hill Book Co., 1922. 555 pp., illus., diagrams, 9 x 6 in., cloth. $5.00.

Recent analytical and experimental investigations of the properties of masonry materials, the forces to which masonry structures are subjected, and the behavior of such structures have contributed largely to the transformation of masonry design and construction from an art to a science. The extensive use of concrete and the development of reinforced concrete have contributed largely to this end. This scientific understanding of masonry design has widened the use of masonry to include many structures for which other materials were formerly used. In addition, more attention is being paid to elegance, grace, and beauty in design. This volume is prepared to furnish a textbook embodying these ideas. An attempt has been made to offer a method of analyzing forces and calculating the resulting stresses and to indicate an acceptable method of design, without extended discussion of questions of interest to engineers rather than students. An effort has been made to keep in mind the æsthetic features of design.

HYDRAULICS WITH WORKING TABLES.

By E. S. Bellasis. Third Edition. N. Y., E. P. Dutton & Co., 1922. 348 pp., tables, illus., 9 x 6 in., cloth. $8.00.

In this edition, the text has been brought thoroughly up to date and subjected to careful and drastic revision. The chief object, is, as before, to deal thoroughly with the facts, laws, and principles of hydraulics, and to keep always in view their practical aspects. Fresh discussions on all the most important coefficients are given and specific recommendations are made. A new set of coefficients for pipes is given. New matter has been added on weirs and weir-like conditions, on discharge measurement by pipe diaphragms, on standing waves, and on the laws governing silting and scour. The book is intended to meet all the requirements both of the student and of the engineer.

CURRENT CIVIL ENGINEERING LITERATURE

KEY TO ABBREVIATED REFERENCES TO PUBLICATIONS INDEXED*

Abbreviated References.	Publication.	Place.
Am. C. Inst	*American Concrete Institute, Proceedings* (Y.)	Detroit
A. I. E. E	*American Institute of Electrical Engineers, Journal* (M.)	New York
A. R. E. A	*American Railway Engineering Association, Proceedings* (Y.)	Chicago
A. S. T. M	*American Society for Testing Materials, Proceedings* (Y.)	Philadelphia
Am. Soc. C. E	*American Society of Civil Engineers, Proceedings* (M.)	New York
Am. Soc. Mun. Impvts	*American Society for Municipal Improvements, Proceedings* (Y.)	New York
Am. W. W. Assoc	*American Waterworks Association, Journal* (Bi-M.)	Baltimore
Am. Wood Prs. Assoc	*American Wood Preservers Association, Proceedings* (Y.)	Baltimore
Ann. P. et C	*Annales des Ponts et Chaussées* (Bi-M.)	Paris
Ann. T. P. Belg	*Annales des Travaux Publics de Belgique* (Bi-M.)	Brussels
Assoc. Ing. Gand	*Annales de l'Association des Ingénieurs sortis des Ecoles Spéciales de Gand* (Q.)	Ghent
Bost. Soc. C. E	*Boston Society of Civil Engineers, Journal* (M.)	Boston
Can. Engr	*Canadian Engineer* (W.)	Toronto
Cem. Eng	*Cement and Engineering News* (M.)	Chicago
Cornell C. E	*Cornell Civil Engineer* (M.)	Ithaca
Dock & Harbour	*Dock and Harbour Authority* (M.)	London
Eisenbau	*Der Eisenbau* (M.)	Leipsig
Eng.	*Engineering* (W.)	London
Eng. Club, St. L	*Engineers Club, St. Louis, Journal* (Bi-M.)	St. Louis
Eng. & Contr	*Engineering and Contracting* (W.)	Chicago
Eng. Inst. Can	*Engineering Institute of Canada, Journal* (M.)	Montreal
Eng. N. R	*Engineering News-Record* (W.)	New York
Engrs. Soc. Pa	*Engineers' Society of Pennsylvania, Journal* (M.)	Harrisburg
Engrs. Soc. W. Pa	*Engineers' Society of Western Pennsylvania, Journal* (M.)	Pittsburgh
Engr.	*Engineer* (W.)	London
Engrs. & Eng	*Engineers and Engineering, Engineers' Club of Philadelphia* (M.)	Philadelphia
Gen. Civ	*Le Génie Civil* (W.)	Paris
Gesund. Ing	*Gesundheits Ingenieur* (W.)	Munich
Inst. C. E	*Institution of Civil Engineers Minutes of Proceedings* (Q.)	London
Inst. Mun. & Co. Engrs	*Institution of Municipal and County Engineers, Journal* (W.)	London
Int. Ry. Assoc	*International Railway Association, Bulletin* (M.)	Brussels
Land. Arch	*Landscape Architecture* (M.)	Harrisburg
Mech. Eng	*Mechanical Engineering* (M.) *Journal of the American Society of Mechanical Engineers*	New York
Mil. Engr	*Military Engineer* (M.)	Washington
Min. & Metal	*Mining and Metallurgy* (M.) *American Institute of Mining Engineers*	New York
Mun. & Co. Eng	*Municipal and County Engineering* (M.)	Indianapolis
N. E. W. W. Assoc	*New England Water Works Association, Journal* (M.)	Boston
N. Y. R. R. Club	*New York Railroad Club, Proceedings* (M.)	Brooklyn
Oest. Ing. Arch. Ver	*Oesterreichischer Ingenieur und Architekten Verein, Zeitschrift* (W.)	Vienna
Power	*Power* (W.)	New York
Rev. Gen	*Revue Générale des Chemins de Fer* (M.)	Paris
Ry. Age	*Railway Age* (W.)	New York
Ry. Main. Engr	*Railway Maintenance Engineer* (M.)	Chicago
Ry. Rev	*Railway Review* (W.)	Chicago
Schw. Bauz	*Schweizerische Bauzeitung* (W.)	Zurich
Sci. Am	*Scientific American* (M.)	New York
Soc. Ing. Civ. Fr	*Société des Ingénieurs Civils de France, Mémoires et Comptes Rendus* (Q.)	Paris
Ver. deu. Ing	*Verein deutscher Ingenieure, Zeitschrift* (W.)	Berlin
West. Ry. Club	*Western Railway Club, Proceedings* (M.)	Chicago
West. Soc. Engrs	*Western Society of Engineers, Journal* (M.)	Chicago
Zeit. Bau	*Zeitschrift fur Bauwesen* (Q.)	Berlin
Z. d. Bauver	*Zentralblatt der Bauverwaltung* (Semi-Weekly)	Berlin

* Y = Yearly ; Q = Quarterly ; M = Monthly ; F = Fortnightly ; W = Weekly.

A. Applied Sciences

a. Processes of Calculation

3. Stresses and Strains

New Studies of Stress Distribution in Irregular Members. George Paaswell. Eng. N. R. Aug. 3, '22.

B. Applied Mechanics

a. Mechanics of Solids (Strength of Materials)

1. Processes of Measurement and Methods of Testing

An Accurate Mechanical Solution of Statically Indeterminate Structures by Use of Paper Models and Special Gages.* George Erle Beggs.* Am. Concrete Inst. '22.

2. Elastic Solids

Die Beanspruchung einer dünnen Zylinderwand bei Berücksichtigung der Formänderung.* (Stresses in a Thin Cylinder Wall, Taking into Consideration the Change in Shape.) Joseph Krebitz. Eisenbau Serial beginning June, '22.

Die Prutschkegelbildung als Grundlage für das Materialprüfwesen.* (Friction Cone Formation as a Basis for Testing Materials.) Friedr. Riedel. Ver. deu. Ing. June 10, '22.

Ueber den Vergleich der näherungsweisen und exakten Berechnung der Spannungsverteilung in einer Röhre.* (Comparison of the Approximate and Exact Calculation of the Distribution of Stresses in a Tube.) Friedrich Willheim. Oest. Ing. Arch. Ver. June 23, '22.

Parallelflanschige Breitflansche-Träger. (Parallel and Broad Flanged Beams.) Schw. Bauz. July 1, '22.

Ueber die Biegungslinien belasteter, inbesondere gedrückter Stäbe.* (On the Flexure Lines of Loaded Columns, Especially Under Compression.) Friedrich Engesser. Z. d. Bauver. July 29, '22.

4. Riveted Systems

Théorie Cinématique du Treillis.* (Kinematic Theory of Latticework.) Léon Légens. Gen. Civ. July 8, '22.

Auf Knickung beanspruchte Gitterstäbe.* (Bending of Loaded Lattice Bars.) Karl Ljungberg. Eisenbau May, '22.

Zur Bemessung genieteter Vollwandträger.* (Proportioning Riveted Plain Web Girders.) Siegmund Schwätzer. Eisenbau May, '22.

5. Homogeneous Inelastic Solids

Designing Concrete Shore Walls. A. W. Consoer. Mun. & Co. Eng. Aug., '22.

6. Heterogeneous Solids (Reinforced Materials)

Eisenbetonmaste mit Rechteckquerschnitt.* ((Reinforced Concrete Mast with Rectangular Cross-Section.) Leopold Herzka. Schw. Bauz. July 8, '22.

Beiträge zur Berechnung von Eisenbeton-Querschnitten auf einheitlicher tabellarischer Grundlage.* (Contribution to the Calculation of Reinforced Concrete Cross Sections on a Uniform Basis.) P. Pasternak. Schw. Bauz. Serial beginning May 27, '22.

7. Pulverulent Masses (Earth Pressure)

Neue Erddruckversuche.* (New Experiments in Earth Pressure.) A. Müllenhoff. Eisenbau July, '22.

b. Hydraulics

1. Processes of Measurement

The California Pipe Method of Water Measurement.* Blake R. Vanleer. Eng. N. R. Aug. 3, '22.

2. Physical Hydraulics (Orifices, Pipes, Channels, Waves)

Ueber die Bewegung des Wassers in offenen Gerinnen.* (The Motion of Water in Open Channels.) Armin Schoklitsch. Schw. Bauz. July 29, '22.

3. Industrial Hydraulics

Queenston-Chippawa Power Development.* F. H. Rogers. Engrs. & Eng. June, '22.

The Queenston-Chippawa 6 000 000-Hp. Hydro-Electric Station.* Power Aug. 22, '22.

Relation of Water Power to the Pulp and Paper Industry in Canada.* J. B. Challies and I. J. Johnston. Am. Soc. C. E. Aug., '22.

Entsandungsanlagen für Wasserkraftwerke. (Sand Removing Apparatus for Hydraulic Power Plants.) H. Keller. Z. d. Bauver. June 3, '22.

x. Miscellaneous

Progress in Hydraulic Science. John R. Freeman. (From Presidential Address at the Annual Convention, Portsmouth, N. H.) Am. Soc. C. E. Aug., '22.

c. Pneumatics

3. Industrial Pneumatics

The Use of Compressed Air in the Ground Work of Public Utilities.* Eng. & Contr. Aug. 9, '22.

Berechnung von Hochdruck-Kompressoren.* (Calculation of High Pressure Compressors.) P. Ostertag. Ver. deu. Ing. June 24, '22.

C. Materials of Construction and General Processes

a. Lime, Cement, Mortar, Concrete, Brick, Bitumen, Timber, Gravel, etc.

Note on Fatigue of Mortar.* W. K. Hatt. Am. Concrete Inst., '22.

Flexural Strength of Plain Concrete.* Duff A. Abrams. Am. Concrete Inst., '22.

Note on the Ball Test Applied to Cement Mortar.* W. K. Hatt. Am. Concrete Inst., '22.

Field Tests to Determine Proportions for Concrete.* Stanton Walker. Am. Concrete Inst., '22.

Proportioning Concrete Mixtures. Duff A. Abrams. Am. Concrete Inst., '22.

Regulations Governing the Form but not the Substance of Standards. Am. Concrete Inst., '22.
Report of Committee VIII—On Masonry.* A. R. E. A., '21.
The Properties of Mineral Aggregates Available in the Metropolitan District.* E. E. Butterfield and C. C. Robesch. Am. Soc. Mun. Impvts., '21.
The Managnan-Sucher Process for Preserving and Transforming Wood. Arthur C. Smith. Am. Soc. Mun. Impvts., '21.
Strength Tests on Pre-Mixed Concrete on Detroit Street Railways. W. R. Dunham. Cem. & Eng. News July, '22.
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Drain Tile Tests Show Concrete Affected by Alkali. (From Technologic Paper No. 214 U. S. Bureau of Standards). Eng. N. R. Aug. 3, '22.
Effets de l'Humidité sur le Béton. (Effects of Moisture on Concrete). Gen. Civ. July 1, '22.
La Nouvelle Fabrique de Ciment de Barcelone (Espagne).* (New Cement Mill at Barcelona (Spain).) Gen. Civ. June 10, '22.
Hygienische Untersuchungen über den Schlackenstein des Nürnberger Gaswerks.* (Hygienic Investigation of Slag Brick from the Nuremberg Gas Works.) Wolfgang Weichardt and Thedor Steinbacher. Gesund. Ing. June 3, '22.
Zement für Siedlungsbauten. (Cement for Small Dwellings.) M. Gary. Z. d. Bauver. June 10, '22.

b. Metals

Ueber die Ermüdung geglühter und vergüteter Kohlenstoffestähle.* (On the Fatigue of Heated and Annealed Carbon Steels.) W. Müller and H. Leber. Ver. deu. Ing. June 3, '22.
Konstruktionsforderungen und Eigenschaften des Stahles.* (Structural Requirements and Properties of Steel.) K. Wendt. Ver. deu. Ing. Serial beginning June 17, '22.
Wesen und Ziele des Eisenschutzes.* (Methods of, and Object in Protecting Iron.) Leo Ivanovszky. Eisenbau July, '22.

c. Preservation and Use of Materials. Painting, Waterproofing

Fundamentals of Waterproofing. Edward D. Boyer. Cem. & Eng. News July, '22.

f. Rock Excavation. Mining. Rock Removal

Abstracts of Institute Papers. Min. & Metal. Aug., '22.
Die maschinelle Gewinnung und Förderung im Steinkohlenbergbau unter Tage. (Mechanical Mining and Hoisting in Coal Mining.) Fr. Herbst. Ver. deu. Ing. Serial beginning June 17, '22.
Die Entwicklung der Maschinentechnik im rheinischen Braunkohlen-Bergbau.* (Development of Mechanical Aids in Mining Rhine Brown Coal.) Grunewald. Ver. deu. Ing. Serial beginning July 1, '22.

g. Execution of Works. Specifications

1. Of Masonry
Making Load Tests of a Tile Wall and Measuring Floor Deflections.* Edward Godfrey. Eng. N. R. Aug. 3, '22.
Das Mauerwerk im alten lübischen Ziegelbau. (Brick Making and Wall Building in Ancient Lubeck.) Delfs. Z. d. Bauver. July 22, '22.
2. Of Concrete
Report of Committee C-3, On Treatment of Concrete Surfaces. Am. Concrete Inst., '22.
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Report of Committee S-5, On Reinforced-Concrete Houses. Am. Concrete Inst., '22.
Concrete Tile in House Construction. Barton E. Brooke. Am. Concrete Inst., '22.
Monolithic Concrete House Construction at Phillipsburg, N. J.* Paul R. Smith. Am. Concrete Inst., '22.
Gun-Stone House at Watertown, Massachusetts.* H. Whittemore Brown. Am. Concrete Inst., '22.
A Special Type of Floor Finish. W. M. Bailey. Am. Concrete Inst., '22.
Cement or Granolithic Finish on Concrete Floors. Joseph C. Grady. Am. Concrete Inst., '22.
Report of Committee P-5, On Fire Resistance of Concrete Building Units. Am. Concrete Inst., '22.
Restoring a Fire Damaged Concrete Building in Berlin.* Eng. N. R. July 27, '22.
Building Reinforced-Concrete Boardwalk at Coney Island.* Eng. N. R. Aug. 10, '22.
Slenderness-Ratio and Strength of Concrete Columns.* F. E. Giesecke. Eng. N. R. Aug. 17, '22.
3. Of Wood
Freitragende Fachwerkbinder in Holz.* (Wide Span Framework of Wood.) Lewe. Eisenbau June, '22.
5. Of Reinforced Concrete
Reinforced-Concrete Fireproof Construction Applied to Home Building. P. J. Hueber. Am. Concrete Inst., '22.
Report of Committee S-1, On Reinforced-Concrete Chimneys. Am. Concrete Inst., '22.
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Die Eisenbeton-Arbeiten bei der Zentrale in Bruck a. d. Mur.* (Reinforced Concrete Work for the Central Station in Bruck a. d. Mur.) Theodor Güdel. Schw. Bauz. June 10, '22.

h. Foundations

Difficult Foundation Problems for Piscataqua Bridge at Portsmouth, N. H. J. W. Rollins. Am. Soc. C. E. Aug., '22.
Nouveau Procédé de Fondations sous l'Eau, Applicable aux Grandes Profondeurs.* (New Process for Subaqueous Foundations, Applicable to Great Depths.) Alfonso Pêna Boeuf. Gen. Civ. July 1, '22.

i. Coffer-dams

Dragline Excavator Handles Earth on Los Angeles Stadium.* Leroy A. Palmer. Eng. N. R. Aug. 3, '22.
Earth-Filled Cofferdam with Concrete Core Wall.* Eng. N. R. Aug. 10, '22.

k. Tunnels and Tunneling-Shields

Driving a Concrete-Block Sewer Tunnel by Shield: Some Troubles and Their Remedies.* John F. O'Rourke. Eng. N. R. Aug. 3, '22.
Eliminating a Tunnel Without Interrupting Traffic.* Eng. N. R. Aug. 3, '22.

x. Miscellaneous

Crushing Plant Engineering. Brownell M'Grew. (Paper read before National Crushed Stone Assoc.) Eng. & Contr. Aug. 16, '22.

D. Highways

c. Construction

Report of Committee on Broken Stone and Gravel Roads With or Without Bituminous Surface Treatments. Am. Soc. Mun. Impvts., '21.
Proposed Specifications for Broken Stone Road. Am. Soc. Mun. Impvts., '21.
Proposed Specifications for a Gravel Road. Am. Soc. Mun. Impvts., '21.
Report of Committee on Specifications for Bituminous Macadam, Bituminous Concrete and Asphalt Block Pavements. Am. Soc. Mun. Impvts., '21.
Report of Committee on Specifications for Sheet Asphalt Paving. Am. Soc. Mun. Impvts., '21.
Specifications for Brick Paving.* Am. Soc. Mun. Impvts., '21.
Report of Committee on Specifications for Sub-Grades and Foundations. Am. Soc. Mun. Impvts., '21.
Report of Committee on Standard Tests for Non-Bituminous Materials. Am. Soc. Mun. Impvts., '21.
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Results Obtained from an Experimental Treated Wood-Block Pavement After Fifteen Years Service.* J. D. MacLean. Am. Soc. Mun. Impvts., '21.
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Bituminous Bound Roads. David W. Johnston. (Paper read before Canadian Good Roads Assoc.) Can. Engr. July 18, '22.
Plant Inspection Necessary to Insure Good Bituminous Pavements. Francis P .Smith. (Paper read before Highway Eng. Conference at the Univ. of Mich.) Mun. & Co. Eng. Aug., '22.
Old Macadam Base for Asphaltic Concrete Pavements.* W. F. Reichardt. Mun. & Co. Eng Aug., '22.
Construction and Maintenance of Gravel Roads in Iowa. C. Coykendall. (Paper read before Highway Engrs.' Assoc.) Mun. & Co. Eng. Aug., '22.
The Use of Black Base. Frank B. McGrane. Mun. & Co. Eng. Aug., '22.
New Road Oil Specifications for Illinois. H. F. Clemmer. Mun. & Co. Eng. Aug., '22.
Methods and Cost of Constructing Experimental Earth Road near Champaign, Ill.* Eng. & Contr. Aug. 2, '22.
High Standard Concrete Roads in North Carolina.* Eng. N. R. Aug. 24, '22.
Contribution à l'Etude des Revêtements Bitumineux. Les Routes "Monolastic" en France. (Contribution to the Study of Bituminous Coatings. "Monolastic" Roads in France.) Charles Mascart. Ann. P. et C. Mar.–Apr., '22.
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d. Maintenance

Granite Block Repaving in Baltimore. Nathan L. Smith. Am. Soc. Mun. Impvts., '21.
The Economical Extent of Pavement Repairs and Maintenance.* George H. Newton. Am. Soc. Mun. Impvts., '21.
Minor Repairs to Sheet Asphalt Paving.August E. Christhilf. Am. Soc. Mun. Impvts., '21.
Co-operative Investigation by the U. S. Bureau of Public Roads Upon the Cause and Correction of Shoving of Asphalt Pavements.* Prevost Hubbard. Am. Soc. Mun. Impvts., '21.
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How a County Maintains Its Gravel Roads. Sam Steigerwait. (Paper read before Iowa Roads Officials.) Eng. & Contr. Aug. 2, '22.
Granite Block Pavement Reconstruction and Asphalt Resurfacing. Jacob Schmitt. (Paper read before City Paving Conference, Philadelphia.) Eng. & Contr. Aug. 2, '22.
How Much Should be Spent on a Road Improvement. N. W. Dougherty. (Paper read before Agricultural and Mechanical College of Texas.) Eng. & Contr. Aug. 2, '22.

e. Street Cleaning, Dust Prevention, Snow Removal

Report of Sub-Committee on Snow Removal. Thomas F. Sullivan. Am. Soc. Mun. Impvts., '21.

h. Vehicles. Automobiles. Traffic

Report of Committee on Traffic and Transportation. Am. Soc. Mun. Impvts., '21.
Mechanical Road Transport.* Thomas Molyneux. Inst. Mun. & Co. Engrs. Aug. 15, '22.
Research in Highway Transport. W. K. Hatt. (From paper read before Am. Road Builders Assoc.) Can. Engr. Aug. 15, '22.

x. Miscellaneous

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The Mechanical Equipment of a Highways Department. A. Dryland. Inst. Mun. & Co. Engrs. Aug. 1, '22.

E. Bridges, Viaducts, and Arches

a. Timber Bridges and Viaducts

Report of Committee VII—On Wooden Bridges and Trestles.* A. R. E. A., '21.
The World's Longest Bridge.* Sci. Am. Aug., '22.

b. Iron or Steel Bridges and Viaducts

Report of Committee XV—Iron and Steel Structures.* A. R. E. A., '21.
Belle Isle Bridge Steelwork Placed by Floating.* Eng. N. R. July 27, '22.
Telescoping Tower on Scow Shifts Arch Centers.* Eng. N. R. Aug., '22.
Eine bemerkenswert rasche Brückenauswechslung.* (A Remarkably Rapid Replacement of a Bridge.) F. Rautschka. Oest. Ing. Arch. Ver. May 26, '22.
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Die neuen Vorschriften der Reichsbahn für das Entwerfen und Berechnen eiserner Eisenbahnbrücken.* (New German Railway Regulations for the Design and Calculation of Iron Railroad Bridges.) Bohny. Z. d. Bauver. June 24, '22.
Versteifte Balkenbrücken.* (Girder Bridges with Increased Rigidity.) K. Kihm. Schw. Bauz. July 1, '22.

d. Concrete and Reinforced Concrete Bridges and Viaducts

Report of Committee S–2, on Reinforced-Concrete Highway Bridges and Culverts.* Am. Concrete Inst., '22.
A Long Time Record of Pier Movement.* M. F. Clements Ry. Main. Engr. Aug., '22.
Design and Construction of Six-Span Reinforced Concrete Highway Bridge Crossing Wabash River at Attica, Indiana.* H. A. Hanapel. Mun. & Co. Eng. Aug., '22.
What One State Highway Bridge Department Has to Do.* Searcy B. Slack. Eng. N. R. Aug. 3, '22.
Sidehill Viaducts Carry Highway in Canyon Above Railroad.* Eng. N. R. Aug. 17, '22.

g. Swing, Bascule, Lift, Floating, Oscillating Bridges; Traveling Cranes

Johnson Street Bascule Bridge, Victoria, B. C.* J. B. Holdcroft. Can. Engr. Aug. 15, '22.

h. Computations, Tests, etc.

Vorläufige Vorschriften über Bau und Unterhaltung der Strassenbrücken in Polen.* (Provisional Regulations on Construction and Maintenance of Highway Bridges in Poland.) M. Thullie. Oest. Ing. Arch. Ver. May 26, '22.
Die Auswertung von Einflusslinien bei gleichmässig verteilter Belastung.* (The Value of Influence Lines in Uniformly Distributed Loading.) H. Kayser. Z. d. Bauver. July 12, '22.

x. Miscellaneous

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Regelquerschnitte für Strassenbrücken.* (Standard Cross Sections for Highway Bridges.) Ellerbeck. Z. d. Bauver. June 21, '22.

F. Inland Waters

b. Canals (General Articles)

Die topographischen und geologischen Verhältnisse beim Bau des Rhein-Herne-Kanals und des Kanals Datteln-Hamm.* (Topographic and Geologic Conditions in Building the Rhine-Herne and Datteln-Hamm Canals.) R. Bartling. Zeit. Bau. Pt. 4, '22.
Der Hansa-Kanal.* (The Hansa Canal.) L. Plate. Ver. deu. Ing. May 27, '22.

c. Regulation of Waterways—Volume of Discharge, Freshets, Floods, Soundings

The St. Maurice River Flow Regulation.* O. LeFebvre. Am. Soc. C. E. Aug., '22.
Curbing the Mississippi.* J. Bernard Walker. Sci. Am. Aug., '22.
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Maximum Flood Discharges in Hawaii.* J. B. Lippincott. Eng. N. R. Aug. 10, '22.
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Die Wirkungen einer Krümmung in offenem Wasserläufen auf Bewegungsvorgang und Bettgestaltung.* (Effect of a Bend in Open Water Courses on the Flow and Bed Formation.) E. Beyerhaus. Zeit. Bau. Pt. 4, '22.
Abflussmengen des Elbe- und Saalgebietes.* (Amount of Run-off from the Elbe and Saal Drainage Areas.) Z. d. Bauver. May 20, '22.
Die Lösung der Rheinfrage.* (The Solution of the Rhine Problem.) Schw. Bauz. Serial beginning June 3, '22.
Schiffshebewerke mit Wagebalken.* (Ship Lift with Scale Beams.) Ellerbeck and Mügge. Z. d. Bauver. June 7, '22.

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Travaux de Canalisation de la Meuse, en Hollande. Le Barrage de Linne (Limbourg).* (Canalization of the Meuse in Holland. Linne Dam (Limbourg).) Alfred Bijls. Gen. Civ. July 8, '22.

h. Boats, Barges

Erfahrungen mit einem für das Schleppamt Hannover erbauten Eisenbetonkahn. (Experiences with a Reinforced Concrete Ship Built for the Hannover Towing Office.) Petzel. Z. d. Bauver. June 3, '22.

j. River and Lake Ports, Equipment

Steamship Dock and Warehouse at Milwaukee, Wis.* Eng. N. R. Aug. 24, '22.

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c. Vessels and Maritime Navigation. Lighthouses and Buoys. Various Signals

Concrete Ships Constructed by U. S. Shipping Board.* Walter R. Harper. Am. Concrete Inst., '22.
The Testing of Materials for Shipbuilding.* M. Leon Guillet (Paper read before Inst. Naval Architects). Engr. July 14, '22.
Further Experiments on Contrary Turning Co-Axial Screw Propellers.* G. Rota. Eng. July 21, '22.
An American High-Speed Cruiser and Its Prototype.* Engr. July 21, '22.
Self-Steering Vessels.* Alfred Gradenwitz. Sci. Am. Aug., '22.
Methods of Stowing Lifeboats on Sea-Going Vessels.* A. Welin. (Abstract of paper read before Japanese Inst. Naval Architects.) Eng. Aug. 4, '22.

d. Roads and Outer Harbors. Dikes and Jetties. Breakwaters

Extension of Fraser River Jetty to Improve Entrance.* Eng. N. R. Aug. 24, '22.

f. Maritime Rivers and Canals. Bank Protection

L'Amélioration du Port de Caen et du Canal de Caen a la Mer.* (Improving Caen Harbor and the Canal from Caen to the Sea.) M. L. Vasseur. Ann. P. et C. Mar.-Apr., '22.

i. Harbors (General Articles)

Shore Protection and Harbor Development Work on the New England Coast. Frank W. Hodgdon. Am. Soc. C. E. Aug., '22.
Shore Protection and Harbor Development Work on the New England Coast. Discussion, Henry S. Adams, Frederic H. Fay, Wildurr Willing and R. S. Patton. Am. Soc. C. E. Aug., '22.
Recent Improvements in Transport Facilities in the Port of London.* Cyril R. S. Kirkpatrick. Dock & Harbour Aug., '22.
The Port of Sydney, New South Wales.* Dock & Harbour Aug., '22.
The Port of Manchester Warehouses at Trafford Park.* Dock & Harbour Serial beginning Aug., '22.

x. Miscellaneous

Marine Borers.* W. G. Atwood. Am. Soc. C. E. Aug., '22.

H. Railroads, Street and Interurban Railways, Automobiles, Aeronautics

a. Railroads

1. General Articles

Report of Committee XX—Uniform General Contract Forms. A. R. E. A., '21.
Report of Special Committee on Standardization. A. R. E. A., '21.
Le Réseau Ferre Marocain. Lignes Construites, en Construction ou Concédées.* (Morocco Railway System. Lines Constructed, under Construction or under Concession). Gen. Civ. June 17, '22.
Le Congrès International des Chemins de Fer (Rome 18-28 Avril 1922.) (The International Railway Congress, Rome, April 18--28, 1922.) Gen. Civ. June 24, '22.
Internationaler Eisenbahn-Kongress. (International Railway Congress.) C. Andreae. Schw. Bauz. June 17, '22.

2. Location

Report of Committee XVI—Economics of Railway Location.* A. R. E. A., '21.
Note Relative: 1° Aux Raccords des Courbes et des Alignements, ou des Courbes entre elles; 2° Aux Raccords des Declivités.* (Note on 1; the Easement and Alignment of Curves, 2: the Easement of Slopes.) M. Descubes. Rev. Gen. June, '22.

3. Roadbed (Grading Construction Work)

Report Committee I—Roadway.* A. R. E. A., '21.

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Report of Committee XVII—Wood Preservation. A. R. E. A., '21.

Report of Committee III—On Ties.* A. R. E. A., '21.
Report of Committee II—Ballast.* A. R. E. A., '21.
Report of Committee IV—On Rail.* A. R. E. A., '21.
Committee V—On Track.* A. R. E. A., '21.
Strengthening Chicago Track Elevation Subways.* Ry. Age July 29, '22.
Some Interesting Tests of Impact Loads on Track Bolts.* Ry. Main. Engr. Aug., '22.
Electrical Resistance of Treated and Untreated Crossties. P. R. Hicks. Ry. Main. Engr. Aug., '22.
Remote Operation of Switches on the New Haven.* Ry. Age Aug. 5, '22.
Determination of Rail Wear for Valuation Purposes.* J. P. Newell. Eng. N. R. Aug. 24, '22.
Eiserne Hohlschwelle, Bauart Scheibe.* (Scheibe Type of Iron Hollow Sleepers.) Alfred Birk. Schw. Bauz. July 22, '22.

5. Signals and Safety Apparatus

Report of Committee X—Signals and Interlocking. A. R. E. A., '21.
Block-System Automatique en Service sur la Grande Ceinture.* (Automatic Block System in Use on the Belt Line.) M. Bernard. Rev. Gen. June, '22.
Une Application du Frein Continu aux Trains de Marchandises en Tunisie.* (The Application of Continuous Brakes on Freight Trains in Tunis.) Louis Tronchère. Rev. Gen. July, '22.
Signaux Electriques pour Chemins de Fer Secondaires.* (Electric Signals for Branch Railroads.) P. Caufourier. Gen. Civ. July 22, '22.

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New Designs of Refrigerator Cars for the Santa Fe.* Ry. Age July 29, '22.
Turbo-Condensing Locomotive Development in Europe.* Ry. Rev. Aug. 12, '22.
Gasoline Switching Locomotive with Hydraulic Drive.* Ry. Age Aug. 19, '22.
L'Eclairage des Trains. Le Remplacement des Divers Eclairages Actuels par l'Eclairage Electrique.* (Train Lighting. Substitution of Electric Lighting for Systems now in Use.) H. Guérin. Gen. Civ. Serial, beginning July 1, '22.
Les Noveaux Wagon-Lits du "Canadian Pacific".* (New Sleeping Cars for the "Canadian Pacific".) Gen. Civ. July 22, '22.
Einphasen-Schnellzuglokomotiven 2-C-1 Einzelachsantrieb Bauart Brown Boveri.* (Single Phase Express Locomotives 2-C-1 with Single Axle Drive of the Brown Boveri Type.) Schw. Bauz. July 8, '22.

7. Use of Electricity

Report of Committee XVIII—On Electricity.* A. R. E. A., '21.
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Santa Fe Completes Modern Shops at Albuquerque.* Ry. Age Aug. 5, '22.
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Proposed Joint Freight Terminals for Chicago. Eng. & Contr. Aug. 16, '22.
Dismantle Jersey City Trainshed of Pennsylvania R. R.* Eng. N. R. Aug. 17, '22.
Eiserner Uebergangsteg im Grenzbahnhofe Teschen a. E.* (Iron Overhead Track Crossings in the Terminal Station at Teschen a. E.) Leopold Herzka. Eisenbau May, '22.
Der Nordbahnhof in Bangkok (Siam).* (Northern Railway Station in Bangkok, Siam.) Gerber. Z. d. Bauver. June 10, '22.
Hochhaus am Bahnhof Friedrichstrasse in Berlin.* (Tall Building at the Friedrichstrasse Railroad Station in Berlin.) Z. d. Bauver. July 29, '22.

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Report of Committee VI—On Buildings.* A. R. E. A., '21.
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How the Illinois Central Overcame a Water Shortage.* Ry. Age Aug. 19, '22.

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Subways for City Transportation.* Robert Ridgway. Am. Soc. Mun. Impvts., '21.

4. Track

Report of Committee on Specifications for Street Railway Pavements Including Track Construction.* Am. Soc. Mun. Impvts., '21.
Drainage of Open Electric Railway Track.* R. P. Waller. (Paper read before Track Maintenance School of Eastern Massachusetts Street Ry. Co.) Eng. & Contr. Aug. 16, '22.

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Cincinnati Double-Deck Terminal for Electric Lines.* Eng. N. R. Aug. 10, '22.

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Electric Vehicles for Municipal Work.* R. B. Mitchell. Inst. Mun. & Co. Engrs. Aug. 15, '22.

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Turbo-Compressors for High-Speed Aviation.* A. Rateau. (Paper read before Inst. M. E.) Eng. Serial beginning July 21, '22.

Les Essais en Vol des Avions Nouveaux au Service Technique de l'Aéronautique.* (Flying Tests of New Airplanes in the Technical Aeronautical Service.) Andre Lesage. Gen. Civ. Serial beginning July 15, '22.

Vom Segelflug-Wettbewerb in Gstaad.* (The Soaring Flight Competition in Gstaad.) Schw. Bauz. June 10, '22.

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Report of Committee on Water-Works and Water Supply. Am. Soc. Mun. Impvts., '21.

Water-Supply of Baltimore.* V. Bernard Siems. Am. Soc. Mun. Impvts., '21.

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After Ashokan—What? S. G. Roberts. Sci. Am. Aug., '22.

Der Ausbau der steirischen Wasserkräfte. (Development of Styrian Water Resources.) Richard Hofbauer. Oest. Ing. Arch. Ver. June 9, '22.

Die Wasserversorgung des Rheinisch-Westfalischen Industriegebietes.* (Water Supply for the Rhine-Westphalia Industrial Region.) E. Link. Gesund. Ing. July 8, '22.

Vergrösserung der Trinkwasserzuleitung in Gotha.* (Enlarging the Water Supply of Gotha.) Schubert. Gesund. Ing. July 15, '22.

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Barrage à Voûtes Multiples, sur le Tirso, à San Chiara d'Ula (Sardaigne).* (Multiple Arch Dam on the Tirso at San Chiara d'Ula, Sardinia.) Gen. Civ. July 22, '22.

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Louisville Sewer Specifications Modified for Contractors. Eng. N. R. Aug. 17, '22.

Neue Erfahrungen bei der Reinigung verwurzelter und verkrusteter Kanalisationsrohrleitungen.* (New Experiences in Cleaning Sewer Pipes Containing Encrustations and Growths.) Schulze. Gesund. Ing. May 27, '22.

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b. Sewage Disposal. Purification

Report of General Committee on Sewerage and Sanitation. Am. Soc. Mun. Impvts., '21.

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Wastes from Pulp and Paper Mills Chemically Considered. H. W. Clark. Am. Soc. C. E. Aug., '22.

Pollution of Streams by Pulp-Mill Wastes. George C. Whipple. Am. Soc. C. E. Aug., '22.

Some Conclusions Drawn from a Recent Survey of Sewage Treatment Plants. H. H. Wagenhals. West. Soc. Engrs. Aug., '22.

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Large Activated-Sludge Plant for Chicago Sanitary District.* Eng. N. R. Aug. 24, '22.
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The Heat Pump.* T. B. Morley. Engr. July 14, '22.
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Ornamental Street Lighting.* L. A. S. Wood. Am. Soc. Mun. Impvts., '21.

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Procédé de Pointage des Projecteurs sur Objectifs Aériens. (Method of Directing Searchlights on Aerial Objects.) M. A. Bochet. Soc. Ing. Civ. Fr. Jan.–Mar., '22.

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Das neue Rathaus in Barmen.* (New Town Hall in Barmen.) Roth. Z. d. Bauver. June 3, '22.
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The Maryland Casualty Company's Building.* Otto G. Simonson. Am. Soc. Mun. Impvts., '21.

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Town Planning and Re-Planning in Great Britain. Herbert H. Humphries. Inst. Mun. and Co. Engrs. July 18, '22.
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PAPERS AND DISCUSSIONS

BOND STRENGTH OF WOOD PILES IN CONCRETE

By R. R. Lundahl,* Assoc. M. Am. Soc. C. E.

Synopsis

This paper has been subdivided, for convenience, in the following manner:

First.—The conditions are discussed that necessitated determining the bond strength of wood piles in concrete in connection with the design of the new sewage disposal plant for Milwaukee, Wis.

Second.—A general description of the test specimens used in obtaining the results contained in this paper, together with their preparation, are given.

Third.—A detailed account, description, and discussion of each of the tests as conducted, are given.

Fourth.—The testing apparatus and the methods of testing are explained.

Fifth.—The combined results are discussed, a table of the results of all the tests is given for ease in comparison, and conclusions from the results are drawn.

General

While plans and specifications were being made by the Sewerage Commission of the City of Milwaukee for the new sewage disposal plant, the question of "the bond strength of wood piles in concrete" had to be considered.

The new plant is to be built at the eastern edge of the city, on what is now a peninsula bounded on one side by Lake Michigan and on the other two sides by the Kinnickinnic and Milwaukee Rivers, respectively. The main part of the plant is to be located on made land, within a pile bulkhead and steel sheet-piling coffer-dam, extending 1 000 ft. into Lake Michigan along the

Note.—Written discussion on this paper which will not be presented at any meeting of the Society, will be closed with the January, 1923, number of *Proceedings*. When finally closed, the paper, with discussion, will be published in *Transactions*.

* Div. Engr., Sewerage Comm., City of Milwaukee, Milwaukee, Wis.

south Harbor Entrance Pier. The coffer-dam has been built, and the area within it has been dredged to the average elevation of the bottom of the aeration and sedimentation tanks that are to be constructed therein.

It will be necessary to place the tanks on pile foundations. With a 16-ton load on each pile, the dead weight of the tanks and the sewage, when the tanks are full, requires an average pile spacing of 5-ft. centers. The weight of the tanks, when empty, is not sufficient to overcome the buoyancy, therefore, it is necessary to anchor the structure to the pile foundation. With a 5-ft. pile spacing, the uplift on each pile averages 6 tons, and the question arose as to whether the skin friction or bond strength of a plain wooden pile in concrete was sufficient to withstand this uplift. A thorough search for information on this subject was made, but no data applicable to the conditions were found. The engineers of the Sewerage Commission favored the use of a mechanical anchorage of some type, although other engineers believed that such anchorage was unnecessary. A majority, however, seemed to favor the deformed type of mechanical anchorage, and this brought up the question of cost. The cheapest method of deforming a pile-head meant an additional cost of at least $1 per pile. As there are about 24 000 piles to be driven, this would entail a minimum additional cost of $24 000, and more elaborate methods of deformation would run as high as $2 or more per pile. This additional expense was not justified without further investigation, because there was no assurance that the deformed anchorage would serve the purpose any better than the plain pile-head. It was decided, therefore, that a series of tests should be conducted, in order to determine whether any type of mechanical anchorage was necessary, and the writer was entrusted with the carrying out of these tests. Thirteen cedar posts, ranging from 6 to 7½ in. in butt diameter, were selected for test specimens. Cedar was chosen because it was available and it was thought that if the tests proved satisfactory on a soft wood, harder woods could be used with a considerable factor of safety. The posts which had been cut in the winter of 1919 and 1920 and stored in the open, were selected at random from a stock pile, the only requirement being that they should be straight.

The posts were prepared for thirteen types of anchorage, some of which differed only slightly. These types will be explained as the results of each test are given. The butts of the posts were cut square, so that a fresh area of the end of the post would be exposed to the concrete, thus giving a condition similar to that when a pile is cut off at grade before it is covered with concrete. The posts were embedded 1 ft. deep in a slab of concrete 4 ft. square and 1 ft. thick, with a sub-slab, directly under the post, 2 ft. square and 1 ft. thick, cast with the larger slab. The object of the sub-slab was to prevent uneven curing effects around the end of the post and to give a condition similar to that obtained in practice. A 1:2:4 mixture of concrete, with washed sand and crushed gravel as the aggregate, was used. The concrete was mixed in a one-bag mixer, and conveyed in a car to a platform, from whence it was shoveled into the forms by hand. The specimens were made in the Casting Plant of the Sewerage Commission, in March, 1921. The building was heated so that there was no possible danger from freezing. The forms were extended about 6 in. above the slab in order that the concrete might be cured

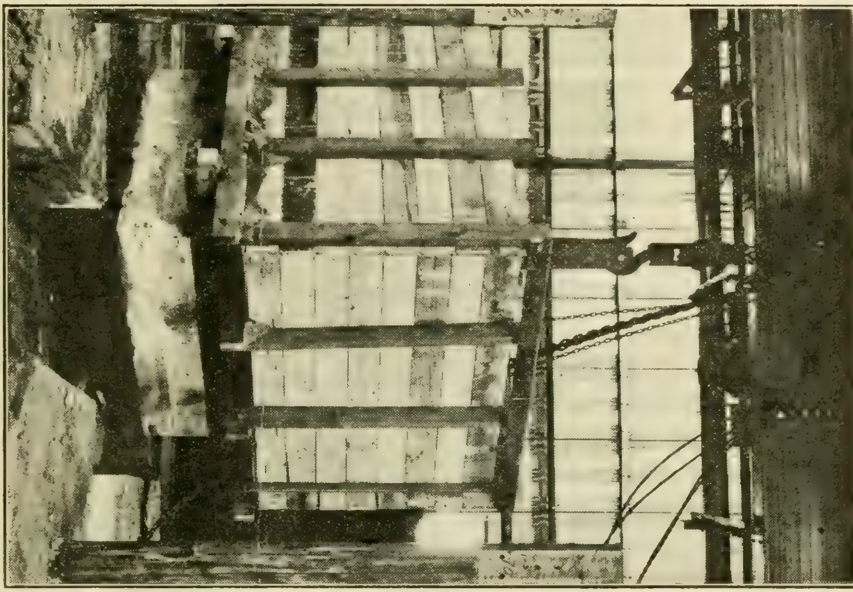

FIG. 1.—LOADING BOX BLOCKED UP 6 IN. ABOVE THE SLAB FOR TESTING.

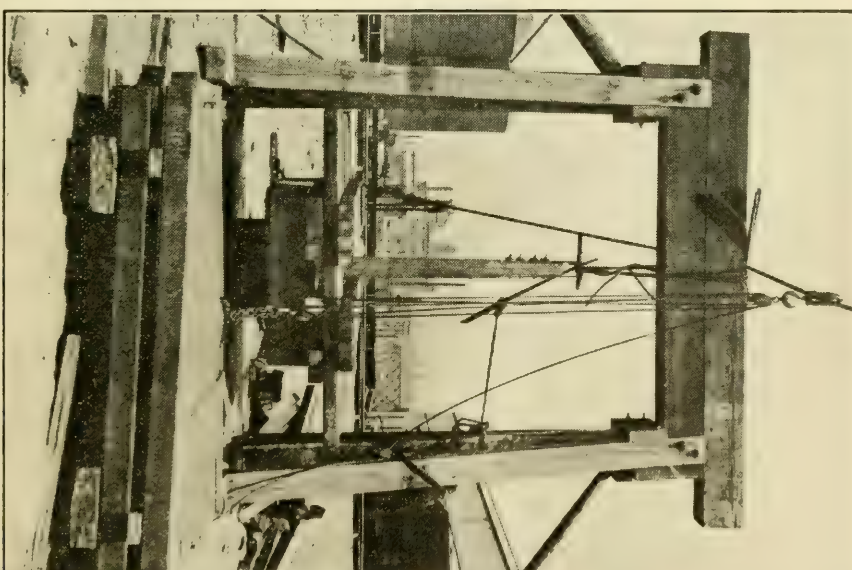

FIG. 2.—VIEW OF TESTING APPARATUS.

under water for 30 days, thus giving a condition similar to that expected in subaqueous work.

Test No. 1.—The specimen for this test was 7½ in. in diameter at the butt, and 7 in. at the concrete surface. The butt was immersed in water for 7 days before it was concreted. This, in the writer's opinion, was the worst condition that could obtain. The concrete was poured on March 24th, 1921, and the specimen was tested on April 27th, five weeks later.

In order that any movement of the concrete could be noted, the loading box was blocked up 6 in. above the slab, as shown in Fig. 1. Another box or shield was built around the post so that no frictional resistance would be caused by the material against it. The net weight per vertical foot of load in the box was 2 797 lb., the box weighed 475 lb., and the concrete anchorage 2 960 lb. The loading of the specimen to the capacity of the box was completed about 11: 00 A. M., April 27th, the total load being 14 760 lb. No movement had been noted at noon, but some time between noon and 2: 00 P. M., the specimen failed, and as no one witnessed the failure, the time the load had been sustained, could not be determined.

The bond area of this specimen was 266 sq. in., and the failure occurred under a sustained load, for bond, of 55.5 lb. per sq. in. The results of the other tests showed that, as far as bond strength was concerned this specimen was tested under the worst condition possible.

Test No. 2.—Specimen No. 2 was similar to Specimen No. 1, except that it was not immersed in water before it was placed in the concrete. The diameter at the butt was 6¾ in. and at the concrete surface, 6⅝ in., and the bond area was 252 sq. in.

The loading was started on May 2d, 1921, the specimen having aged 5 weeks and 5 days. In order to determine the exact point of failure, the load was applied as shown in Table 1.

TABLE 1.

Load, in pounds.	Time.	Date.	Hours. load was sustained.
7 200	9:00 A.M.	May 2, 1921	6
8 300	3:00 P.M.	" 2, "	23
9 700	2 00 P.M.	" 3, "	21
10 200	11:00 A.M.	" 4, "	5
11 000	4:00 P.M.	" 4, "	19
11 500	11:00 A.M.	" 5, "	5
12 000	4:00 P.M.	" 5, "	43
13 400	11:00 A.M.	" 7, "	21
12 500	8:00 A.M.	" 8, "	31
13 700	3 00 P M.	" 9, "	22
14 100	1:00 P.M.	" 10, "	23
14 800	12 00 Noon	" 11, "	48
19 500	12:00 Noon	" 13, "	1½
21 000	1:30 P.M.	" 13, "	18½

At 21 000 lb., the capacity of the crane had been reached, and this load was allowed to remain until 8: 00 A. M., May 14th, when the specimen was lowered and the load removed. A bond strength of 83.3 lb. per sq. in. had been developed with no sign of failure.

It was decided to move all the specimens to the open, build a gallows-frame strong enough to carry a much heavier loading, and use billet steel for loading purposes. The concrete blocks were covered with about 6 in. of wet sand to prevent shrinkage in the posts. In spite of this precaution, considerable shrinkage took place.

The test of Specimen No. 2 was resumed on June 1st. A 10 200-lb. load was placed on the specimen by 5: 00 P. M., and allowed to remain over night. On examination at 8:00 A. M., June 2d, a slight cleavage was noted. When the load was increased to 13 000 lb., the post pulled from the concrete about ⅛ in. When the load was increased to 16 000 lb., the movement was about ¼ in., but it was so gradual that it could not be observed during the loading. The load was then increased, in 360-lb. increments, to 19 500 lb., at which loading, the post was pulled entirely from the concrete.

A 21 000-lb. load had been applied previously on this specimen without any sign of failure, and the cause of failure at a lesser load is attributed to the shrinkage of the post during the 18 days it had been in the open without being kept wet, except for the moisture in the sand covering. The weather during this period was exceptionally warm most of the time, and the slight rainfall drained off quickly.

Test No. 3.—Specimen No. 3 was immersed in water for 7 days before it was concreted. The diameter at the butt was 7⅞ in. and, at the concrete line, 7⅜ in. The concrete had aged 71 days when the loading of the specimen was started on June 2d. The load was placed in 360-lb. increments and totaled 17 400 lb., at 6:30 P. M. No failure could be noted, and the load was allowed to remain until noon the following day, when it was observed that the post had pulled ⅛ in. from the slab. The failure, under a sustained load of 17 400 lb., was equivalent to a bond strength of 60.6 lb. per sq. in. The load was increased to 20 300 lb., and the post pulled gradually to ¼ in., which was considered sufficient evidence of failure, and further operation was discontinued.

To guard against the conditions in Test No. 2, the remaining test specimens were thoroughly soaked, and the result of Test No. 3 shows that it was helpful.

Test No. 4.—Specimen No. 4 was dry when the concrete was poured and had aged 72 days when the loading was started at 3: 30 P. M., on June 3d. The diameter of the post at the butt was 7⅝ in. and, at the concrete line, 7¼ in. A 16 000-lb. load had been applied by 8: 30 P. M., with no indications of failure. This load was allowed to remain until 10: 00 A. M., June 4th, 13½ hours, but no signs of failure were noted. The load was increased to 19 520 lb. and allowed to remain until noon, June 6th, at which time the bond strength appeared to have failed slightly, but there was some doubt as to this fact. The load, therefore, was increased to 23 840 lb., at which a slight movement was noted, and at 25 640 lb., the post had been pulled ¾ in. The specimen was now unloaded, and it was settled definitely that failure had occurred at 19 520 lb. which was equivalent to a bond strength of 69.7 lb. per sq. in.

Test No. 5.—Specimen No. 5 was 7 in. in diameter at the butt and $6\frac{11}{16}$ in. at the concrete line. The concrete was banked up about 4 in. around the post in the form of a cone. The idea was that the area of concrete in con-

tact with the pile would be increased at little added expense. This method was considered to be the next cheapest, if the results of the tests on the plain anchorages proved to be inadequate.

This specimen had aged 75 days when the loading was started at 7 : 45 P. M., on June 6th. At 8: 30 P. M., a load of 10 960 lb. had been applied, which was allowed to remain until noon on June 7th, with no sign of failure. The load was then increased to 25 640 lb. by 8 000, 5 000, and 2 000-lb. increments, respectively, and at 7 : 00 P. M., the first sign of failure was noted. Further loading to 28 160 lb. resulted in the failure of the cedar post in tension.

If the embedded depth of the post is taken as 12 in., a bond strength of 100 lb. per sq. in. was developed. If the embedded area of the post is used, the bond strength was 75.8 lb. per sq. in. The cedar post failed in tension under a unit stress of about 850 lb. per sq. in.

Test No. 6.—Specimen No. 6 was of the same type as Specimen No. 5, but had a slightly larger butt diameter. The concrete had aged 79 days when the loading was started at 9:00 A. M. At 11:00 A. M., a load of 16 200 lb. had been applied when the first sign of failure was noted. A bond strength of only 60.0 lb. per sq. in. had been developed.

The load was increased to 23 120 lb., at which the post pulled from the concrete. The post was found to be sound, but there had been no bond to the bottom of it, whereas, in the other tests, this was not the case. The area of the bottom of the post was about 33 sq. in., and the bond on this area would have had a material affect on the total load sustained.

In the foregoing tests, the unit stresses have been calculated from the areas of the sides alone, but the bond to the bottoms undoubtedly plays an important part. The exact relation could not be determined except by tests.

When Specimen No. 6 was concreted, the post settled so that it was embedded more than 12 in. in the concrete. Accordingly, it was pulled up to the 12-in. mark. In doing this, the bond to the bottom of the post must have been destroyed. The results seem to indicate that the bond to the end fibers plays a more important part than that to the sides of the post.

Test Specimens Nos. 1 to 6

Tests Nos. 1 to 6 complete all those without any type of deformed anchorage. The conclusions from these tests are that the enlargement of the pile-head has no effect on the load sustained until the bond strength has failed. In every test, it was noted that, when the bond failed, the concrete usually dropped suddenly about ⅛ in., and then continued to move slowly to ¼ in. Between the ⅛ and the ¼-in. movement, the enlargement of the head became effective. In nearly every case, after this point had been reached, the load was applied without additional failure until the post either broke or pulled from the concrete.

The writer believes that as long as the concrete adheres to the bottom of the post, there is no chance for the fibers to compress. This is probably the cause of the sudden drop as soon as the bond has failed. The load necessary to overcome the bond was sufficient to compress the fibers enough to allow the concrete to drop the ⅛ in. After this, an additional load was necessary to compress the fibers sufficiently to allow the post to be pulled even slightly.

A movement of $\frac{1}{8}$ in. might be injurious to a structure, and where it is necessary for the piles to withstand any upward pressure, it is unsafe, therefore, to consider anything but the bond strength of the concrete to the wood pile. It would seem safe to consider the bond strength of the concrete to the wood pile to be 50 lb. per sq. in., which is below any of the results obtained, but the entire static head should be used in designing, in order to obtain an additional factor of safety.

Whether a pile of larger diameter than those used would develop a similar bond strength can be determined only by tests. The Sewerage Commission intends to conduct a series of such tests, in order to secure this information.

Tests on the Deformed Specimens

Test No. 7.—Specimen No. 7 had an average butt diameter of $6\frac{3}{4}$ in. and no enlargement. Four 3-in. track spikes were driven, 90° apart, into the butt, the heads extending about 1 in. for anchorage. The concrete in this specimen had aged 80 days, and the test was started at 8:30 A. M., June 10th. At 11:00 A. M., after a load of 16 640 lb. had been applied, the first sign of failure was noted, the post having pulled about $\frac{1}{8}$ in. The load was increased to 17 360 lb., and as the post continued to pull from the concrete, the test was stopped. The bond area, on the sides, was 257 sq. in., and the bond stress developed was 64.7 lb. per sq. in.

Test No. 8.—This specimen had a diameter of $7\frac{1}{16}$ in. and an enlargement of $\frac{3}{16}$ in. A 1-in. pin, 30 in. long, was passed through a 1-in. hole drilled through the post 6 in. from the bottom. About 1 ft. of the pin extended from each side of the post. The concrete had aged 81 days when the loading was started at 1:45 P. M., June 10th. At 4:00 P. M., a load of 18 080 lb. had been applied and no signs of failure had been noted. This load was allowed to remain until 8 A. M., June 11th, when it was increased to 22 040 lb., under which, at 8:50 A. M., the first sign of failure was observed. The load was increased to 22 400 lb. and the post pulled about $\frac{1}{8}$ in., which load is equivalent to 84.4 lb. per sq. in. on the bond area.

The test was stopped, as it had already failed beyond the point of safety. No doubt, the pin through the post increased the load that this specimen could sustain. After the failure of the bond, which probably occurred before the line of fracture was noted, the specimen held until the fibers in contact with the pin had compressed. When this occurred, the post pulled from the concrete and the line of failure was noted.

Test No. 9.—Specimen No. 9 had an average butt diameter of $7\frac{1}{8}$ in., and 1 ft. from the butt, it was sawed on two opposite sides to a depth of 1 in. The wedges thus formed, tapering to 1 in. at the concrete line, were then chopped out, thus making the post $7\frac{1}{8}$ in. in diameter at the butt, and, at the concrete line, a flattened ellipse, 5 by 7 in.

The concrete had aged 81 days when the loading was started at 11:30 A. M., and by 2:00 P. M., a load of 16 280 lb. had been applied when the first sign of failure was noted. The bond strength developed was 61.2 lb. per sq. in. The load was increased as follows: 17 360 lb., $\frac{1}{4}$-in. movement; 18 080 lb., $\frac{5}{8}$-in. movement; and 18 520 lb., 1-in. movement. At 22 400 lb., the post pulled

from the concrete. Examination disclosed that there had been no shearing action; the fibers had been compressed, and pulled through the 5-in. hole in the concrete.

The preparation of piles in this manner would be expensive, and the results of the test show that this added expense would be unwarranted.

Test No. 10.—This specimen was 6⅝ in. in diameter and had been expanded by driving a 1 by 12 by 6½-in., hard-wood wedge flush with the butt, thus making the bottom of the post elliptical in shape, 6⅝ by 7⅝ in. Before the wedge was driven, a band was placed around the post at the concrete surface, which band was not removed during the test. This specimen was 83 days old. The load was started at 8:45 A. M., and by 11:15 A. M., the first sign of failure was noted with a load of 15 920 lb., which is equivalent to a bond strength of 63.7 lb. per sq. in. Under a load of 18 800 lb., the post had pulled ¼ in., and ⅜ in. with 20 240 lb. It was seen that this method did not increase the bond strength, and the loading was not continued.

Test No. 11.—Specimen No. 11 was trimmed to a wedge shape on four sides, instead of two sides, as was done with Specimen No. 9. The average diameter of the butt was 6½ in. and, at the concrete line, the post was about 4½ in. square.

The concrete in this specimen had aged 84 days and the first sign of failure was noted with a load of 13 760 lb. With a bond area of about 244 sq. in., this load was equivalent to 56.4 lb. per sq. in. From this result, it is obvious that the trimming of a pile-head to this shape would not be justified. When the load was increased to 18 080 lb., the post pulled from the concrete about ¼ in., and at 22 400 lb., it pulled ½ in. After remaining for 2 hours without further movement, the load was increased to 23 840 lb., at which the post parted at the concrete line, under a load of 1 180 lb. per sq. in.

Test No. 12.—Specimen No. 12 was prepared by driving two wedges in the butt at right angles to each other. An iron band was placed around the post, 1 ft. from the butt, before the wedges were driven. The band was used to give the same results as would be obtained from the soil around the pile-head if the wedges were driven in the field, after the piles were in place. On this specimen, the band was removed before the test was started.

This test began on June 14th, at 3:00 P. M., and continued, with 360-lb. increments, until noon, on June 15th, when the first sign of failure was noted with a load of 15 200 lb. The average diameter at the butt was 6⅝ in., and the bond area, disregarding the increase in size due to the wedges, was 240 sq. in., thus giving a unit bond strength of 63.3 lb. per sq. in.

In Test No. 10, with one wedge, the unit bond strength was 63.7 lb. These results would indicate that there would be no reason for using more than one wedge. This method of deformation would be considerably cheaper than trimming the post to a wedge shape, and also gives a higher unit strength, but there is no indication that the bond strength would be any greater than that in an anchorage without any deformation.

The driving of wedges in the pile-heads would not injure the original surface fibers, as would be the case if the methods in Tests Nos. 9 and 11 were followed; but there would always be some "give" between the post and the

wedges, and, as the load was applied, this "give" would cause the bond to break sooner than in a solid post.

Test No. 13.—In Specimen No. 13, two 1-in. pins at right angles to each other had been driven through holes in the post, 6 in. from the butt. The pins extended 1 ft. into the concrete, on four sides.

The post had a slight butt enlargement, an average diameter of 6½ in., and a bond area of 240 sq. in., after deducting for the area of the pins. The loading was started on June 16th at 8:00 A. M., and by 11:00 A. M., a load of 15 920 lb. had been applied, when failure was noted. This load was allowed to remain, but no further failure occurred. A bond strength of 66.3 lb. per sq. in. had been developed, but the failure had been so slight that the movement would not have been injurious to any structure. In fact, there was a question as to whether the slight fracture noted was really a failure due to the pulling out of the post, or whether it was due to the elongation of the wood fibers at the concrete line. The latter cause would seem to be the more plausible, because, under continued loading, no further movement was noted.

Under a load of 20 600 lb., the post parted, and the movement at the concrete line was found to be small. A bond strength of about 86 lb. per sq. in. had been developed without an injurious amount of movement.

The pin types of deformation are by far the cheapest that were tried, and the results indicate that only one pin would be necessary, if it was decided that a deformed anchorage was needed.

Description of Testing Apparatus and the Method of Testing

Fig. 2 shows the testing apparatus. The gallows-frame was designed to carry a load of 40 tons.

The method of testing was as follows: A locomotive crane would swing the specimen under the frame so that the pin could be inserted through the sling and the shackle-plates, the sling being of such length that the specimen was clear of the ground when it was released by the crane. The steel billets, each of which weighed 360 lb., were handled by a block and tackle running on a trolley. They were lowered with the least possible jar to the specimen and were racked so that a clear space was left around the post for observation and as a guard against friction of the load on the post. The post and the concrete adjacent to it were thoroughly chalked before loading was started, in order that any movement could be better detected. The increments of load were applied slowly, and as the point of failure was reached, the specimen was closely watched for any sign of such failure. As soon as the slightest line appeared, the loading was stopped for a time, in order to allow the post to pull as much as possible under that load. The points of failure were determined closely from the results of the test on Specimen No. 2 which was loaded in small increments and allowed to stand for several hours before additional load was applied.

Conclusions

Table 2 gives the results of the tests and affords an oportunity for comparing the different types of anchorage tested, for drawing conclusions as to

TABLE 2.

Test no.	Type of anchorage.	Diameter at butt, in inches.	Diameter at concrete line, in inches.	Enlargement, in inches.	Total load sustained, in pounds.	Area, in square inches, of sides in bond.	Area of butt, in square inches.	Bond strength (sides), in pounds per square inch.	Bond strength, sides and bottom, in pounds per square inch.	Remarks.
1	No deformation	7⅛	7	⅛	14 760	266	39.9	55.5	48.2	Pile butt soaked for 7 days before being concreted.
2	"	6¾	6⅝	⅛	21 000	252	35.8	83.3	72.9 cu. ft. dry	
3	"	7⅞	7⅜	½	17 400	287	48.7	60.6	51.8	Pile butt soaked as in Test No. 1.
4	"	7⅝	7¼	⅜	19 520	280	45.6	69.7	59.9	Butt dry.
5	Concrete banked up about 4 in.	7	6 11/16	5/16	25 640	258–338	38.5	100–75.8	68.1	Post pulled apart at 28 160 lb.
6	Concrete banked up about 4 in.	7½	7⅛	⅜	16 280	276	44.2	59.0	......	No bond to the bottom.
7	Four small track spikes driven	6⅞	6¾	⅛	16 640	257	37.1	64.7	56.6	Total movement ¼ in. at a load of 17 360 lb.
8	1-in. pin through butt one way	7 1/16	6¾	5/16	22 040	260	39.0	84.4	74.0	Total movement ⅛ in., load of 22 400 lb.
9	Trimmed to a wedge shape on two sides	7⅛	7	⅛	16 280	266	39.9	61.2	53.2	Post pulled out, load, 22 400 lb
10	Expanded 1 in. by wedge driven into butt	6⅝	6⅝	None	15 920	250	34.5	63.7	55.9	Total movement ⅜ in., load 20 240 lb.
11	Butt trimmed to wedge shape, four sides	6⅝	6⅜	¼	13 760	244	34.5	56.4	49.4	Post broke at top of concrete, load, 23 840 lb.
12	Butt expanded two ways by two wedges	6⅜	6⅜	None	15 200	240	31.9	68.3	55.9	Post pulled out, load, 25 280 lb.
13	Two 1-in. pins at right angles through butt	6⅝	6⅝	¼	15 920	245	34.5	66.3	57.0	Post broke at load of 20 600 lb. Movement at breaking point very slight.

the best types to be used, and for determining a safe average bond strength to be used in designs where it is necessary to use the factor of bond strength.

The average bond strength of nine of the tests, not including those immersed in water and those with the pins, was 66.3 lb. per sq. in., when the side area only is considered. Using the combined area of the side and bottom, the average is 58.9 lb. per sq. in. For the piles without deformed anchorage, that is, the first seven, not including the specimens that had been immersed, which are obviously low, but including the test with the spikes, the average strength is 70.5 lb. per sq. in., whereas the average of the deformed anchorages is only 65.9 lb. per sq. in. These results indicate that deformation of the pile-heads has a tendency to decrease the bond strength.

The average strength of the two plain anchorages, Tests Nos. 2 and 4, is 76.5 lb. per sq. in., whereas the average of the two highest tests of deformed heads, the two with pins, is 75.3 lb. per sq. in. Therefore, the results shown by the two best deformed types are not as good as those found with the two plain anchorages.

In conclusion, it may be stated that only the bond strength of the wood to the concrete should be considered. The deformation of the pile-heads does not warrant the added expenditure it will entail. If the substance to be anchored is of metal, a deformed anchorage will be beneficial.

The writer believes that the Sewerage Commission will not consider the use of deformed pile-heads, but will rely on the bond of the concrete to the pile. The piles to be driven will have an average butt diameter of at least 12 in. and are to be embedded to a depth of 10 in. in the concrete. The side area, in bond, is 377 sq. in., and with 12 000 lb. of uplift per pile, a bond strength of 31.9 lb. per sq. in. is necessary. This is less than the lowest result obtained in any of the tests.

The work that brought about the foregoing tests is being done for the Sewerage Commission of the City of Milwaukee under the direction of T. Chalkley Hatton, M. Am. Soc. C. E., as Chief Engineer, with James L. Ferebee, M. Am. Soc. C. E., as Principal Assistant Engineer.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications.

THE COMPARISON OF CONCRETE GROINED ARCHES AS AN AID IN THEIR DESIGN

By Philip O. Macqueen,* Assoc. M. Am. Soc. C. E.

Synopsis

Most engineers recognize the value of comparison as an aid in the design of practically all structures, both as a valuable check and also as a preventative of unusual errors. Comparison, however, must be used with good judgment and extreme caution, as otherwise dangerous mistakes may easily be made. Comparisons cannot be used, in some instances, with special or original structures, but these cases are a small percentage of the total.

With statically indeterminate structures, such as concrete groined arches, the use of comparison as an aid to design becomes doubly valuable. Actual design in this case is impossible, and the engineer must use empirical methods and comparisons. Empirical formulas alone could not be safely used in the design of concrete groined arches, and comparisons, therefore, become fundamentally important.

This paper presents a study of the proportions of typical concrete groined arches which have been used successfully for reservoir roofs. It is believed that the various ratios and dimensions discussed will be helpful in problems of design and that the use of these ratios will save, not only a great deal of the work of preliminary design, but will serve also as a guide to more economical structures. Special types of concrete groined arches built to support unusually heavy loads, such as filter tanks, are not included in the scope of this paper.

As one of the problems of Civil Engineering the groined arch, now generally used for reservoir roofs, is an interesting anomaly. The method of designing

Note.—Written discussion on this paper which will not be presented at any meeting of the Society, will be closed with the **January, 1923**, number of *Proceedings*. When finally closed, the paper, with discussion, will be published in *Transactions*.

* Bay City, Mich.

the structure is empirical and from a strict mathematical or even logical viewpoint, its exact design is impossible. This type of structure has been used, however, for more than 2 000 years, and, when carefully constructed, its safety is beyond question. It is as safe or, perhaps, safer than the ordinary arch used in bridge or in building construction. The singularity of the groined arch roof lies in the condition that a structure so simple, strong, and harmonious, is so complicated as regards a mathematical analysis of its stresses, even under a symmetrical loading. The purpose of this paper is to make a comparison of existing groined arches and to suggest several rules that should be of use in the design of such structures.

The usual methods attempted in the design of concrete groined arches are based on the principles that are used in the design of simple cylindrical arches. These methods, as applied to concrete groined arches, have been fully developed by Thomas H. Wiggin,* M. Am. Soc. C. E., and also by Leonard Metcalf,† M. Am. Soc. C. E. It is unnecessary, therefore, to repeat the complete mathematical analysis. The method, although simple, is somewhat cumbersome, and is not completely presented in textbooks. The article by Mr. Wiggin contains several methods of designing groined arches, but for the purpose of this paper, it will be sufficient to summarize briefly the generally preferred method.

In general, there are two steps in this preferred method of design: First, the selection of a groined arch of certain dimensions; and, second, the investigation of this arch for stability under the required loadings by the "hypothesis of least crown thrust." This hypothesis assumes that the true "line of resistance" is that for which the thrust at the crown of the arch is the least possible consistent with equilibrium. The strength and stability of the arch depend on the position of the "line of resistance" and the position of this line, in turn, depends on the amount, direction, and point of application of the crown thrust. The crown thrust is assumed to act horizontally at the upper third point of the thickness of the arch at the crown. The external loading in this case is considered as acting on a triangular area obtained by assuming that the arch is cut vertically along the groined lines, as this method of loading will be found to give greater unit stresses at the "joint of rupture" than other methods. As a condition of equilibrium, it is further assumed that the center of pressure will always remain within the middle-third of every joint. With these assumptions and correct data in regard to the dead and the live loads, the crown thrust and the thrust at the joint of rupture are easily (although somewhat laboriously) computed by means of the usual methods as given in textbooks on simple cylindrical voussoir arches. The final step in the design consists in laying out a cross-section of the arch on a large scale, and making a careful graphical check of the problem and the position of the "lines of resistance" for the various loadings.

The preferred method of design previously outlined, although cumbersome, has always produced safe structures and, therefore, it is used. With good

* *Engineering Record*, March 12th, 1910, p. 298.

† *Transactions*, Am. Soc. C. E., Vol. XLIII (1900), p. 37.

concrete, the factor of safety is high, as has been proved many times. Arches designed for the normal loading of 2 ft. of earth plus a live load of 100 lb. per sq. ft. have safely carried a load of 10 ft. of earth. Cases are also on record of other arches carrying heavy concentrated loads far in excess of those anticipated. As an example of a still more severe test, arches unsupported at the crown have been loaded to at least four times the allowable load, thus proving the strength of the structure. Groined arch roofs have failed, but, in each case, the failure has been due to faulty foundations, poor concrete, or to unusual stresses at certain times during construction. No cases are on record of groined arches that have failed on account of poor design or even excess loading.

TABLE 1.—Data on Concrete Groined Arches for Reservoir Roofs.

No.	Date	Location.	Clear span (2 a), in feet.	Rise of intrados (b), in feet.	Crown thickness (t), in feet.	Rise of extrados (h), in feet.	Span, center to center, of columns (2 c), in feet.	Ratios:		Average thickness of roof, in feet.
								$\left(\frac{b}{2a}\right)$	$\left(\frac{h}{b+t}\right)$	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	1903	Watertown, N. Y.	10.000	1.500	0.500	0.833	11.500	0.150	0.417	0.562
2	1909	Providence, R. I.	10.250	2.500	0.500	1.250	11.917	0.244	0.417	0.635
3	1903	Ithaca, N. Y.	10.500	1.500	0.500	0.833	12.000	0.143	0.417	0.568
4	1909	Springfield, Mass.	11.333	2.000	0.500	1.250	13.000	0.177	0.500	0.566
5	1911	Toronto, Ont., Canada	11.333	2.000	0.500	1.167	13.000	0.177	0.467	0.582
6	1910	Owen Sound, Ont., Canada	11.500	2.500	0.500	1.167	13.000	0.218	0.388	0.625
7	1903	Washington, D. C.	11.833	2.500	1.500	1.417	13.667	0.211	0.472	0.606
8	1899	Albany, N. Y.	11.917	2.500	0.500	0.500	13.667	0.210	0.167	0.774
9	1900	Superior, Wis.	12.000	2.500	0.500	0.500	13.667	0.208	0.167	0.747
10	1903	Washington, D. C.	12.167	2.500	0.500	1.417	14.000	0.206	0.472	0.600
11	1912	Roland Park, Md.	13.000	2.667	0.500	1.500	14.667	0.205	0.473	0.593
12	1907	Philadelphia, Pa.	13.167	3.000	0.500	1.750	15.000	0.228	0.500	0.609
13	1907	Lawrence, Mass.	13.167	2.750	0.500	1.667	15.000	0.209	0.513	0.590
14	1908	Pittsburgh, Pa.	13.167	3.000	0.500	1.750	15.000	0.228	0.500	0.609
15	1904	Philadelphia, Pa.	13.417	3.000	0.500	1.750	15.250	0.224	0.500	0.607
16	1913	Baltimore, Md.	13.500	3.000	0.500	1.750	15.000	0.222	0.500	0.582
17	1912	Grand Rapids, Mich.	13.833	3.000	0.500	1.833	15.000	0.217	0.524	0.543
18	1907	Philadelphia, Pa.	14.000	3.000	0.500	1.750	15.833	0.214	0.500	0.604
19	1902	Milford, Mass.	14.000	3.000	0.500	1.500	16.000	0.214	0.428	0.658
20	1909	Springfield, Mass.	14.000	2.750	0.500	1.500	16.000	0.196	0.462	0.623
21	1916	Cleveland, Ohio	14.080	3.500	0.500	2.000	15.750	0.249	0.500	0.618
22	1908	Columbus, Ohio	15.167	3.167	0.500	1.917	16.833	0.209	0.522	0.568
23	1905	Washington, D. C.	15.500	3.500	0.500	2.083	18.000	0.226	0.522	0.646
24	1908	Pittsburgh, Pa.	15.750	4.000	0.500	2.167	18.000	0.254	0.482	0.683
25	1912	New York City	16.000	3.750	0.500	2.000	18.000	0.234	0.470	0.653
26	1913	Minneapolis, Minn.	16.333	3.500	0.500	2.000	18.000	0.214	0.500	0.600
27	1913	Montreal, Que., Canada	17.000	4.250	0.500	2.000	19.000	0.250	0.422	0.700
28	1912	New York City*	18.000	4.500	0.500	2.500	20.000	0.250	0.500	0.646
29	1912	New York City*	19.160	5.000	0.500	2.58[illegible]	22.000	0.261	0.469	0.744
30	1920	Cleveland, Ohio*	17.960	4.500	0.500	2.500	20.292	0.253	0.500	0.675

* Under construction or proposed.

Notwithstanding this proved strength, however, the method of designing groined arches is empirical, and a strict mathematical or even logical method of their design is impossible. This statically indeterminate condition is due principally to the multiplicity of the points of support so that, although the loading on the groined arch roofs is symmetrical and easy to compute, it is, nevertheless, practically impossible to develop a formula that will give a logical distribution of the stresses caused by the loading. The flat slab type of concrete structure is statically indeterminate for the same reason. The

preferred method of design for groined arch roofs is that which gives the greatest unit stresses and, therefore, the highest factor of safety. The labor involved in this method can be appreciated by the fact that the average engineer, unless experienced in this work, usually will require a month to lay out, investigate, check, compare, and finally select a groined arch for an important structure. Simple, rational formulas have replaced the lengthy methods originally used in the design of flat slab roofs so that it is consistent with economical engineering practice that, if possible, the complicated method of design of groined arches should be replaced with much simpler methods.

Strength and economy are the two most important items in the design of groined arches. Table 1 presents a comparison of thirty typical groined arches. The dimensions and general data for most of these arches have been taken from a table compiled by John H. Gregory, M. Am. Soc. C. E., and published in an article* by J. W. Armstrong, M. Am. Soc. C. E. The arches are listed according to the length of span. The ratios given in Columns 9 and 10 and the average thicknesses of the groined arch roofs given in Column 11, have been calculated by the writer.

Table 2 gives a summary of the various unit stresses and crown thrusts obtained in a few typical arches. In each case, the stresses were calculated by the method of "least crown thrust" as outlined previously.

TABLE 2.—UNIT STRESSES AND CROWN THRUSTS CALCULATED BY METHOD OF "LEAST CROWN THRUST" FOR THREE TYPICAL GROINED ARCHES.

No.	Clear span ($2a$), in feet.	Rise of intrados (b), in feet.	Crown thickness (t), in feet.	Rise of extrados (h), in feet.	Span, center to center, of columns ($2c$), in feet.	ARCH STRESSES FOR LOADING OF 2 FT. OF EARTH, PLUS LIVE LOAD OF 100 LB. PER SQ. FT.			
						Crown thrust, in pounds.	Maximum unit compression at crown, in pounds per square inch.	Maximum unit compression at joint of rupture, in pounds per square inch.	Maximum unit shear, in pounds per square inch.
1	17.96	3.75	0.50	2.25	20.292	5 310	148	267	59
2	17.96	4.00	0.50	2.25	20.292	5 120	142	238	55
3	17.96	4.50	0.50	2.50	20.292	4 640	129	210	51

Tables 1 and 2 present a number of interesting comparisons which will be discussed in the order of their importance.

(*a*).—*Form of Groined Arch Roofs.*—The form of groined arch reservoir roof invariably selected by designing engineers consists of one in which the intrados is formed by semi-elliptical cylindrical surfaces and the extrados by parabolic cylindrical surfaces. The arches listed in Tables 1 and 2 are of this type. The elliptical shape of the intrados lends itself to a systematic arrangement at the column supports and the flattened form of the arch allows for long spans with a minimum loss of head-room. The parabolic extrados,

* *Engineering Record,* November 15th, 1913.

in its turn, gives a uniformly increasing thickness to the arch. Taken together, the two curves are excellently adapted for groined arch reservoir roofs, and it is difficult to conceive that more effective curves could be used.

(*b*).—*Length of Span.*—The length of span is more a question of economy than of strength, although strength is an important item for investigation. If the columns are long, the span should also be long, in order to save concrete by a reduction in the number of columns. The calculations must also include the average thicknesses of the roofs, and several comparisons should be made. Confidence in the strength of groined arch roofs has increased rapidly in the past twenty years and the tendency is to use longer spans than was customary in the early days. Spans as short as 10 ft. would hardly be considered at the present time, unless the groined arch roof was intended to support very heavy loads, such as filter tanks. For columns less than 20 ft. in length, the average span used at present is about 15 ft., center to center of columns; whereas for columns 20 to 30 ft. in length, the span is usually 18 to 20 ft. A span of 20 ft. is probably the maximum which could be recommended for groined arch roofs.

(*c*).—*Crown Thickness.*—As shown in Table 1, the crown thickness in every case has been taken as 6 in., and the comparison, therefore, is simple. It might be argued that the crown thickness for the arches with the shorter spans could be less than that given, but this is not the case. With the loads in question (normally 2 ft. of earth plus a live load of 100 lb. per sq. ft.), the 6-in. thickness is about the minimum that could be recommended. Engineers feel responsible for the safety of the structures they design and hesitate to use excessively thin sections, although calculations may indicate that such sections are thicker than necessary. It will be readily seen, however, from Table 2, that a thickness greater than 6 in. is uncalled for, as all the compressive unit stresses at the crown are less than 150 lb. per sq. in. A reasonable increase in the loading, or in the length of the span, would possibly give a maximum compressive unit stress at the crown of 300 lb. per sq. in., but even this would be safe. The use of 6 in. for the crown thickness for all concrete groined arch reservoir roofs, therefore, does not seem to be unreasonable.

(*d*).—*Average Thickness of Roof.*—In order to make a study of the economy of the several groined arches selected for comparison, it is necessary to calculate the volume of concrete contained in each. This study is easily made by formulas derived by Mr. John H. Gregory and W. B. Fuller, M. Am. Soc. C. E. The volume (V) of a single square groined arch roof section (Fig. 1), above the springing line of the intrados is calculated as follows:

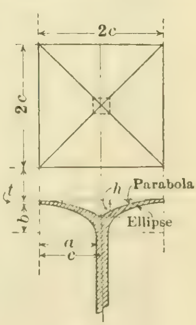

FIG. 1.

$$V = m + n - p$$

$$m = 4b\left[c^2 + \frac{2}{3}a^2 - \frac{\pi}{2}a\,c\right]$$

$$n = 4c^2\,t$$

$$p = \frac{2}{3}c^2\,h$$

in which,

a = one-half the clear span;
b = rise of intrados;
c = one-half of the span, center to center, of columns;
h = rise of extrados; and
t = crown thickness.

When the clear span, crown thickness, and span, center to center, of columns, have been selected, the quantities, $4\left[c^2 + \frac{2}{3}a^2 - \frac{\pi}{2}a\,c\right]$ and $4\,c^2\,t$, become constants which may be expressed by k and k'. The formula for volume then becomes:

$$V = b\,(k) + k' - \frac{2}{3}\,c^2\,h$$

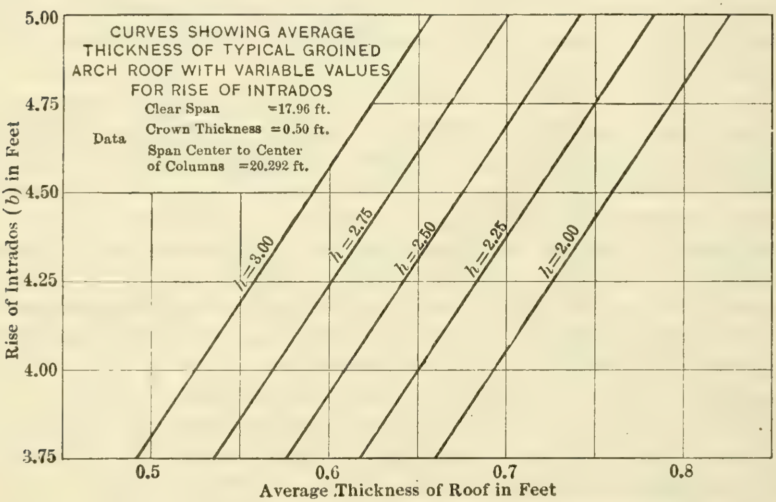

Fig. 2.

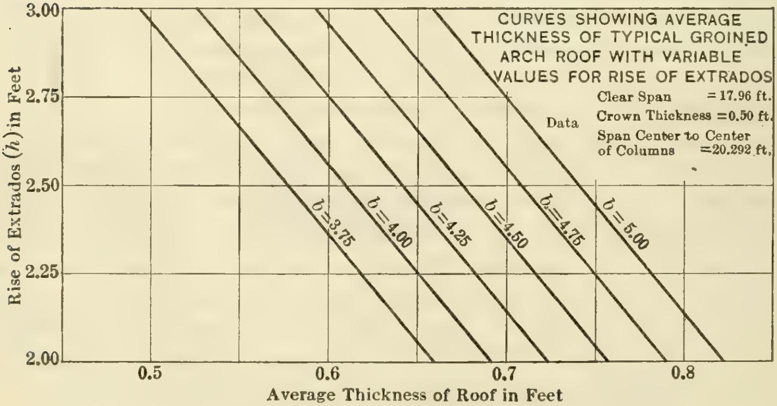

Fig. 3.

The average thickness of the groined arch roof, which is a convenient method of expressing the volume, is then obtained by dividing the volume by ($4c^2$) the total projected area of the groined arch section. All dimensions should be given in feet. Tables 3 and 4 have been calculated in order to show the effect of the change of the rise of the intrados and extrados on the volume of concrete. In Table 3, the rise of the intrados has been made the variable and, in Table 4, the rise of the extrados has been made the variable. The curves (Figs. 2 and 3) have been plotted from the results given in Tables 3 and 4. It will be observed that the average thicknesses of the groined arch roofs increase directly with the increase in the rise of the intrados and inversely with the rise of the extrados. For the purpose of comparison, tables and curves similar to those just mentioned should be prepared for each new span selected for investigation. It will also be found that the average thickness decreases directly with the span. The volumes of concrete contained in the columns must be included in the final comparison.

TABLE 3.—Calculated Average Thicknesses of a Typical Groined Arch Roof with Variable Values for the Rise of Intrados.

No.	Clear span ($2a$), in feet.	Rise of intrados (b), in feet.	Rise of extrados (h), in feet.	Crown thickness (t), in feet.	Span, center to center, of columns ($2c$), in feet.	Ratios. $\left(\frac{b}{2a}\right)$	Ratios. $\left(\frac{h}{b+t}\right)$	Average thickness of roof, in feet.
				0.50				
1	17.96	3.75	2.00	0.50	20.292	0.209	0.471	0.661
2	17 96	4.00	2.00	0.50	20.292	0.223	0.445	0.693
3	17.96	4.25	2.00	0.50	20.292	0.237	0.422	0.726
4	17.96	4.50	2.00	0.50	20.292	0.252	0.400	0.758
5	17.96	4.75	2.00	0.50	20.292	0.265	0.381	0.792
6	17.96	5.00	2.00	0.50	20.292	0.278	0.364	0.825
7	17.96	3.75	2.25	0.50	20.292	0.209	0.530	0.618
8	17.96	4.00	2.25	0.50	20.292	0.223	0.500	0.652
9	17.96	4.25	2.25	0.50	20.292	0.237	0.474	0.684
10	17.96	4.50	2.25	0.50	20.292	0.252	0.450	0.718
11	17.96	4.75	2.25	0.50	20.292	0.265	0.428	0.750
12	17.96	5.00	2.25	0.50	20.292	0.278	0.409	0.782
13	17.96	3.75	2.50	0.50	20.292	0.209	0.588	0.577
14	17.96	4.00	2.50	0.50	20.292	0.223	0.556	0.610
15	17.96	4.25	2.50	0.50	20.292	0.237	0.526	0.642
16	17.96	4.50	2.50	0.50	20.292	0.252	0.500	0.675
17	17.96	4.75	2.50	0.50	20.292	0.265	0.476	0.708
18	17.96	5.00	2.50	0.50	20.292	0.278	0.454	0.742
19	17.96	3.75	2.75	0.50	20.292	0.209	0.647	0.536
20	17.96	4.00	2.75	0.50	20.292	0.223	0.612	0.567
21	17.96	4.25	2.75	0.50	20.292	0.237	0.580	0.602
22	17.96	4.50	2.75	0.50	20.292	0.252	0.550	0.634
23	17.96	4.75	2.75	0.50	20 292	0.265	0.524	0.666
24	17.96	5.00	2.75	0.50	20.292	0.278	0.500	0.700
25	17.96	3.75	3.00	0.50	20.292	0.209	0.706	0.494
26	17 96	4.00	3.00	0.50	20.292	0.223	0.667	0.526
27	17.96	4.25	3.00	0.50	20.292	0.237	0.632	0.558
28	17.96	4.50	3.00	0.50	20.292	0.252	0.600	0.593
29	17 96	4.75	3.00	0.50	20.292	0.265	0.572	0.625
30	17.96	5.00	3.00	0.50	20.292	0.278	0.545	0.657

(e).—*Rise of Intrados.*—The rise of the intrados is usually considered one of the more difficult questions to solve in the design of groined arch roofs, as this factor involves a question of both strength and economy. Fig. 4, plotted from data given in Table 1, shows the comparison of the rise of the intrados to the clear span. The rise of the intrados is observed to increase gradually

with the increase of the clear span, and the average rate of this increase is shown by the curve in Fig. 4, the equation of which is:

$$y = \frac{x}{3} - 1.5$$

or,

$$b = \frac{2\,a}{3} - 1.5.$$

TABLE 4.—Calculated Average Thicknesses of a Typical Groined Arch Roof with Variable Values for the Rise of Extrados.

No.	Clear span (2 a), in feet.	Rise of intrados (b) in feet.	Rise of extrados (h), in feet.	Crown thickness (t), in feet.	Span, center to center, of columns (2 c), in feet.	Ratios $\left(\frac{b}{2\,a}\right)$	Ratios $\left(\frac{h}{b+t}\right)$	Average thickness of roof, in feet.
1	17.96	3.75	2.00	0.50	20.292	0.209	0.471	0.661
2	17.96	3.75	2.25	0.50	20.292	0.209	0.530	0.618
3	17.96	3.75	2.50	0.50	20.292	0.209	0.588	0.577
4	17.96	3.75	2.75	0.50	20.292	0.209	0.647	0.535
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11	17.96	4.25	2.00	0.50	20.292	0.237	0.422	0.726
12	17.96	4.25	2.25	0.50	20.292	0.237	0.474	0.684
13	17.96	4.25	2.50	0.50	20.292	0.237	0.526	0.642
14	17.96	4.25	2.75	0.50	20.292	0.237	0.580	0.602
15	17.96	4.25	3.00	0.50	20.292	0.237	0.632	0.558
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17	17.96	4.50	2.25	0.50	20.292	0.252	0.450	0.718
18	17.96	4.50	2.50	0.50	20.292	0.252	0.500	0.675
19	17.96	4.50	2.75	0.50	20.292	0.252	0.550	0.634
20	17.96	4.50	3.00	0.50	20.292	0.252	0.600	0.593
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24	17.96	4.75	2.75	0.50	20.292	0.265	0.524	0.666
25	17.96	4.75	3.00	0.50	20.292	0.265	0.572	0.625
26	17.96	5.00	2.00	0.50	20.292	0.278	0.364	0.825
27	17.96	5.00	2.25	0.50	20.292	0.278	0.409	0.782
28	17.96	5.00	2.50	0.50	20.292	0.278	0.454	0.742
29	17.96	5.00	2.75	0.50	20.292	0.278	0.500	0.700
30	17.96	5.00	3.00	0.50	20.292	0.278	0.545	0.657

The rise of the intrados to be used in the average groined arch roof, therefore, may be expressed as being approximately equal to one-third of the clear span minus the constant (1.5). The effect of the rise of the intrados on the strength of the groined arch is shown in Table 2, in which it may be noted that the unit stresses and the unit shares decrease steadily with the rise of the intrados. Referring to Tables 3 and 4 and Figs. 2 and 3, however, it is observed that the average thickness of the groined arch roof increases directly with the increase of the rise of the intrados. These two conditions, therefore, are opposed to each other, and it is necessary to make a careful study of both in order to arrive at a logical selection of the most suitable dimensions.

The ratio of the rise of the intrados to the clear span is given in Column 9 of Table 1. As this ratio varies between the approximate limits of 0.20 and 0.25, the rise of the intrados, therefore, may also be expressed as approximately equal to one-fifth of the clear span for the shorter spans and one-fourth of the clear span for the longer spans.

(*f*).—*Rise of Extrados.*—The rise of the extrados used in the average groined arch is given in Table 1, in which also (Column 10) is given the ratio $\left(\frac{h}{b+t}\right)$ of the rise of the extrados to the sum of the rise of the intrados and the crown thickness. In general, this ratio is observed to have an approximate value of 0.50, and the average rise of extrados to be used, therefore, may be expressed as being equal to one-half of the total rise of the arch, that is, the sum of the intrados and the crown thickness. It will be observed further that the unit stresses increase directly with the rise of the extrados and that the average thickness of the arch increases inversely with the rise of the extrados. These two conditions, therefore, are also opposed to each other, and it is necessary to make a careful study of both in order to make a logical selection of the most suitable dimensions.

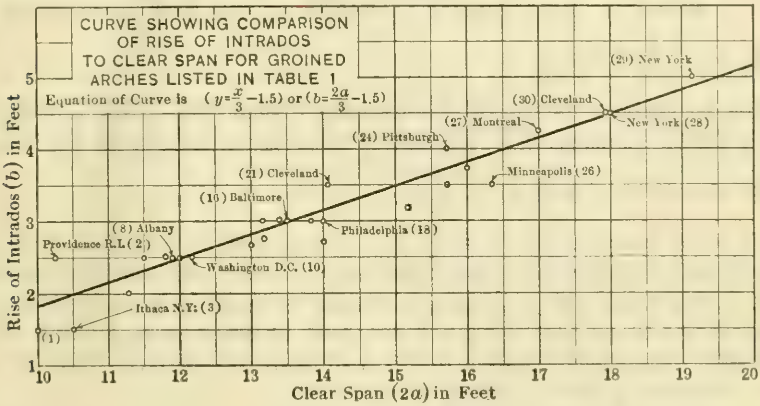

FIG. 4.

(*g*).—*Unit Stresses and Loadings.*—As shown in Table 2, the compressive unit stresses obtained in the calculations for groined arch roofs are much lower than those normally used in the design of other concrete structures. As a result of this condition, the specifications generally call for concrete containing a relatively small quantity of cement, the proportions of the mix usually selected being either 1:2.5:5 or 1:3:5. The saving in cost of the cement alone over a 1:2:4 mix, therefore, is from 5 to 10 per cent. In a structure containing 10 000 cu. yd., and with concrete at $15 per cu. yd., this saving would be about 2% of the total cost. In this connection, it is well to call attention to certain other phases of this question. In the first place, the unit stresses obtained are hardly more than guesses and it is not altogether wise to place too much confidence in the calculations. In the second place, the calculated unit shears are relatively high and there is, perhaps, danger in this condition in case extremely lean concrete mixtures are used. In general, it is believed to be unwise to use concrete mixtures leaner than 1:2.5:5, and, in many cases, a 1:2:4 concrete is perhaps preferable.

Summing up the various comparisons, it will be convenient to express the final results in the form of a few simple rules, as follows:

(*a*).—The form of groined arch roof in which the intrados consists of a semi-elliptical cylindrical surface and the extrados of a parabolic cylindrical surface is excellently adapted to this type of construction and, therefore, it should be used.

(*b*).—Spans from 15 to 20 ft., center to center, of columns may be used with safety. Economy will always call for long columns with long spans. In selecting the most suitable length of span, the calculations should always include the volume of concrete in the roof.

(*c*).—A crown thickness of 6 in. may be used satisfactorily for practically all groined arch reservoir roofs.

(*d*).—The average thickness or volume of the groined arch reservoir roof should be calculated carefully for all trial arches selected, as this factor is an important guide in the determination of the most suitable arch to be used.

(*e*).—In general, the rise of the intrados (taken only to the nearest 0.25 ft.) should be about equal to one-third of the clear span minus 1.5, that is, $b = \frac{2\,a}{3} - 1.5$.

(*f*).—In general, the rise of the extrados (taken only to the nearest 0.25 ft.) should be about equal to one-half of the sum of the rise of the intrados and the clear span, that is, $h = \frac{b + t}{2}$.

(*g*).—The unit stresses obtained in the calculations should be used with caution, and it should be realized that these stresses are somewhat problematical. In general, the proportions of concrete used in groined arch roofs should be not leaner than a 1:2.5:5 mix, and, in many cases, a 1:2:4 mix is preferable. The normal loading for the roof is usually taken as 2 ft. of earth plus a live load of 100 lb. per sq. ft.

The question of whether to use a groined arch or a flat slab roof for a reservoir is one which frequently involves differences of opinion. Both types are acceptable, although, in certain cases, one type is preferable to the other. For small, shallow reservoirs of an area of, say, less than 1 acre, the flat slab roof may be more economical, on account of the lower cost of form work, and, perhaps, better standardized methods of construction. For larger and deeper reservoirs, however, covering an area of several acres, the groined arch roof will prove much more economical than the flat slab roof.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

LOCOMOTIVE LOADINGS FOR RAILWAY BRIDGES

Discussion*

By Messrs. C. D. Purdon, Robert C. Strachan, Victor H. Cochrane, Albert Lucius, B. A. Worthington, G. H. Gilbert, J. A. L. Waddell, Gustav Lindenthal, R. A. Caughey, J. C. Ralston, J. C. Bland, J. M. Johnson, C. S. G. Rogers, E. A. Stone, Harold C. Bird, Almon H. Fuller, Carlton T. Bishop, Clyde W. MacCornack, and C. P. Disney.

C. D. Purdon,† M. Am. Soc. C. E. (by letter).‡—The author appears to assume that, at some time, all railroads will have to provide for such engines as the enormous ones described in the paper. Although it is true that cars of any kind may be encountered on any railroad, they may be pulled by small engines, and bridges should provide for these as a minimum. Such engines as those described in the paper are for exceptional places, very heavy tonnage, and heavy grades, and are not likely to be found on roads which do not have such grades and business. The load of heavy cars, expressed as weight per foot, does not express their effect on bridges. For instance, the car of the Norfolk and Western Railroad Company, of 5 346 lb. per ft., has a maximum effect in shear of a little more than E-48 and in moment, of E-47. A gondola of the Pennsylvania System, of 3 980 lb. per ft., overloaded 10%, has a maximum effect of E-44.5 when in solid trains, but if alternated with 80 000-lb. cars fully loaded, it has an effect of E-31 on spans of 60 ft. and more.

The typical engine described by the author does not resemble an engine and is only a load per foot and his M loading might as well be used. This would require a purchaser to turn the engine he desires into M loading. Although the tractive power of M is not given—as it generally runs about 22% of weight on drivers—an M loading, on a line with maximum grades of 0.5%, would haul more cars than could be handled.

* This discussion (of the paper by D. B. Steinman, M. Am. Soc. C. E., published in the May, 1922, *Proceedings*, and presented at the meeting of the Society of September 6th, 1922), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† Cons. Engr., St. Louis South Western Railway, St. Louis, Mo.

‡ Received by the Secretary, June 9th, 1922.

In preparing the 1920 specifications, the Iron and Steel Structures Committee of the American Railway Engineering Association, canvassed carefully all kinds of loading and finally decided on the Cooper series as being the most suitable. The specification is for spans of 300 ft. and less; for longer spans, the same loading "per foot" could be used, and, for long spans, the floor and some members are designed by the Cooper loading, but the trusses are on a "per foot" basis.

The author states that his M loading provides for future increase. The A.R.E.A. loading also allows for a future increase by using a unit stress of 16 000 lb., after adding impact. This has been criticized by some engineers. Why not use the actual safe stress of, say, 20 000 or 22 000 lb. per sq. in.? If the M loading allows for increase, consider it with a unit stress of 20 000 lb., which is the same as adding 25% to the Cooper loading. Then, taking Fig. 6* and adding 25% to the Cooper E-60 brings a curve practically the same as M-60 up to 80 ft., after which it is a little above that loading. Few railroad companies in the West would care to build their trestle bridges for such a loading.

Some years ago, the writer made a comparison of different kinds of engines, with the Cooper loading, using E-55 as a base. Through the courtesy of the Baldwin Locomotive Works, many diagrams were obtained. These diagrams were reduced to an equivalent load of 55 000 lb. on each driving axle, and either the shear or the moment was plotted, the highest value being used, but as the following load is only an assumption, the supposed bridge was a deck girder up to 120 ft. This diagram† indicates that the engines of the Santa Fé type would make a fairly regular curve up to 120 ft., as they probably would not be "double-headed". A following load of about 7 000 lb. (which is about the weight per foot of the engine itself) might be used. With regard to the Cooper loading not representing the actual, consider the effect of a consolidation engine (double-headed), rated at about E-42, on a 200-ft. span originally built for the Cooper A, which is approximately E-25. The Cooper rating will range from E-37.58 to E-39.59 for the lower chord members, and from E-37.65 to E-45.61 for the web members.

The Santa Fé type seems to be a favorite; Record 88 of the Baldwin Locomotive Works, which is dated 1917, states that between 1903 and 1906, the Atchison, Topeka and Santa Fé Railway Company had bought 160 locomotives and had since bought 32 more; that the Chicago, St. Paul, Minneapolis and Omaha Railway Company had bought 2 engines; the Texas and Pacific Railway Company, 26; the Duluth, Missabe and Northern Railroad, 6; the Chicago Great Western, 7; the Union Pacific, 27; the Chicago, Burlington and Quincy, 66; the Lehigh Valley, 76; the Southern, 55; the St. Louis, San Francisco, 60; the Bessemer and Lake Erie, 20; the Baltimore and Ohio, 30; the Erie, 20; and, to-day, 50 are on their way to the Southern Pacific.

The average weight of these locomotives (all super-heater) is 548 745 lb.; on drivers, 294 482 lb.; tractive power 72 973 lb. (equal to 24.78%); length, 81 ft. 9 in.; weight per foot, 6 596 lb.; and weight per pound of tractive power,

* *Proceedings*, Am. Soc. C. E., May, 1922, p. 1059.

† Published in *Engineering News*, of October 23d, 1913, but without the Erie Triplex.

7.52. Comparing these with nine Consolidated locomotives, taken at random, we have: Weight, 336 155 lb.; on drivers, 191 711 lb.; tractive power, 46 008 lb. (equal to 24%); length, 68 ft.; weight per foot, 4 938 lb.; and weight per pound of tractive power, 7.36. Six ten-wheelers gave 22% tractive power, with an average weight per pound of tractive power of 10.22. This indicates that the Santa Fé type carries no more load in proportion than a Consolidated engine, not superheated, and less than a ten-wheeler.

Robert C. Strachan,* M. Am. Soc. C. E. (by letter).†—The author has performed a valuable work by his analysis of the bases underlying much present practice in specifying train loads, and by making evident some of the inconsistencies involved in attempting to adapt to present-day conditions an ancient generalization, which, although excellent in its day, has outlived its usefulness. His constructive suggestions merit the careful consideration of the bridge engineer, and are especially timely in view of the current discussion of the "Tentative Specifications for Steel Railway Bridges," submitted by the Special Committee on Bridge Design and Construction.

A reading of the paper compels one to realize that, although stresses and sections computed to the "twentieth part of one poor scruple", rivets numbered and placed with the minutest attention to primary, secondary, even tertiary stress, and impact coefficients determined with the utmost refinement, the completed structure may be far from good, if not designed for the loads actually to be carried at once, or reasonably to be expected during its life.

The author's recommendations as to a new specification of the amount and distribution of train loads, based on his study of much pertinent data, are advanced in three forms, the second and third of which are derived from the first, and are shown to possess advantages due to possible simplifications in mathematical processes. These advantages are of undoubted weight; but the second and third forms are "implicit functions" of the first, reflecting all its possible imperfections, and tending to remove the nub of the argument a step farther in any discussion of the merits of the author's suggestions.

It would seem preferable in drawing any specification, to state the fundamental requirements, rather than the results of conclusions drawn therefrom by methods which themselves may be open to argument. Accordingly, confining the discussion to the proposed conventional axle-load diagram (Fig. 7‡), the author's determination of M-60 after careful study of the stress-producing effects of the heaviest existing locomotives, and his subsequent building up of a series of M diagrams bearing simple ratios to M-60, in the manner of the Cooper loading, is an important step in the direction of introducing a scientific and modern standard load system for the economical design of railroad bridges and for the rating or comparison of their carrying capacities; a system of which the need is great in consequence of the changes in locomotive construction which have taken place since the Cooper system of loading was devised.

Although professional opinions may differ as to the degree of approximation to the truth attained in the use of the proposed conventional system, its adoption would tend toward augmented economy and the elimination of

* New York City.
† Received by the Secretary, June 12th, 1922.
‡ *Proceedings*, Am. Soc. C. E., May, 1922, p. 1060.

many unprofitable complications inseparable from the use of an obsolete load specification.

Although it is the writer's opinion that neither the second nor the third form of the author's recommendations should appear as a load specification, both of them, with the accompanying diagrams, will commend themselves as "short-cuts" for use under suitable circumstances.

VICTOR H. COCHRANE,* M. AM. SOC. C. E. (by letter).†—The author's tables and diagrams clearly show that, in the Cooper series, there is a lack of balance between the locomotive axle concentrations and the uniform train load. The maximum axle load is ten times as great as the train load per linear foot, whereas in the case of the heaviest loadings now in use this ratio is about thirteen. For some locomotive loadings the discrepancy is not so great; for instance, the last three loadings of the group of seven presented by the author are fairly well represented by the Cooper E-60 loading. However, if these same locomotives were followed by a lighter uniform loading, such as the 210 000-lb. cars assumed by a committee of the American Railway Engineering Association‡ in its study of the moments and shears produced by modern locomotives and cars, the Cooper loading would again be out of balance. It seems desirable, therefore, to make the axle loads heavier in proportion to the uniform train load than is done in the Cooper series.

Modern locomotives differ so greatly in the arrangement and spacing of axle loads that no single type can be found to represent all of them, unless it is a more or less conventional system, such as the author's first alternative loading. A composite loading derived from a number of different types of heavy locomotives will undoubtedly be more nearly representative of future loadings than any single loading series, and, consequently, will make more adequate provisions for future developments in locomotive design.

Of the three alternative loadings proposed, the writer prefers the loading formula, as it is by far the simplest and most direct. There seem to be two principal objections to its use: First, that it does not give a graphic picture or diagram of the axle concentrations and uniform load to which it corresponds; and, second, that it is not in close enough agreement with the composite loading. These objections are outweighed by the advantages which are well stated by the author.

In regard to the first objection, which relates to the lack of a loading diagram, there is no reason why an approximate equivalent loading, such as the author's first alternative, should not be used in connection with the formula to show approximately the loads provided for.

Concerning the second objection, that relating to the differences between the formula loading and the composite loading, it may be pointed out that, inasmuch as different locomotives in use give widely different results, and as there is no way of knowing exactly the future trend of locomotive design, these discrepancies are of minor consequence.

However, if desirable to do so, it is practicable to devise a formula which will agree much more nearly with the composite loading than that of the

* Cons. Engr. (Cochrane, Willrich and Johnson), Tulsa, Okla.

† Received by the Secretary, June 19th, 1922.

‡ *Proceedings*, Am. Ry. Eng. Assoc., Vol. 21.

TABLE 5.—VALUES OF EQUIVALENT LOADS AS DERIVED FROM HEAVIEST LOCOMOTIVE LOADINGS AND AS GIVEN BY PROPOSED FORMULAS.

Span length, in feet.	END SHEARS.					MOMENTS AT QUARTER-SPAN.					MOMENTS AT MID-SPAN.				
	Heaviest locomotive loading, in pounds. (Plate XIII*).	As given by author's formula.		As given by proposed formula.		Heaviest locomotive loading, in pounds. (Plates XII† and XIII).	As given by author's formula.		As given by proposed formula.		Heaviest locomotive loading, in pounds. (Plate XIII).	As given by author's formula.		As given by proposed formula.	
		Amount.	Percentage of variation.	Amount.	Percentage of variation.		Amount.	Percentage of variation.	Amount.	Percentage of variation.		Amount.	Percentage of variation.	Amount.	Percentage of variation.
10	22 600	23 970	+ 6.1	23 210	+2.7	....	....	....	....	....	....	....	....	....	....
20	18 400	18 420	+ 0.1	17 980	−2.3	14 670	16 620	+13.3	15 780	+7.6	14 580	14 490	−0.6	15 580	+6.9
30	15 460	15 960	+ 3.2	15 330	−0.8	13 900	14 490	+ 4.3	13 730	−1.2	13 480	12 750	−5.4	13 530	+0.4
40	13 500	14 490	+ 7.3	13 500	0.0	12 700	13 220	+ 4.1	12 510	−1.5	12 320	11 710	−4.9	12 310	−0.1
50	12 230	13 480	+10.2	12 070	−1.3	11 420	12 350	+ 8.1	11 670	+2.2	11 400	11 000	−3.8	11 470	+0.6
60	11 600	12 740	+ 9.8	11 450	−1.3	10 750	11 710	+ 8.9	11 050	+2.8	10 820	10 480	+1.5	10 850	+5.1
70	11 260	12 170	+ 8.1	10 980	−2.5	10 360	11 210	+ 8.2	10 580	+2.1	10 120	10 070	−0.5	10 380	+2.6
80	10 940	11 710	+ 7.0	10 590	−3.2	10 100	10 800	+ 6.9	10 190	+0.9	9 900	9 740	−1.6	9 990	+0.9
90	10 600	11 325	+ 6.8	10 270	−3.1	9 890	10 480	+ 6.0	9 870	−0.2	9 720	9 470	−2.6	9 670	−0.5
100	10 374	11 000	+ 6.0	10 000	−3.6	9 670	10 200	+ 5.5	9 600	−0.7	9 480	9 240	−2.5	9 400	−0.8
120	9 860	10 480	+ 6.3	9 560	−3.0	9 200	9 740	+ 5.9	9 160	−0.4	9 040	8 870	−0.8	8 960	−0.9
140	9 440	10 070	+ 6.7	9 230	−2.2	8 860	9 390	+ 6.0	8 830	−0.3	8 640	8 590	−0.6	8 630	−0.1
160	9 090	9 740	+ 7.1	8 950	−1.5	8 500	9 110	+ 7.2	8 550	+0.6	8 400	8 350	−0.6	8 350	−0.6
180	8 815	9 475	+ 7.5	8 730	−1.0	8 300	8 870	+ 6.9	8 330	+0.4	8 120	8 160	+0.5	8 130	+0.1
200	8 590	9 240	+ 7.6	8 540	−0.6	8 090	8 670	+ 7.2	8 140	+0.6	7 840	8 000	+2.0	7 940	+1.3
220	8 397	9 045	+ 7.7	8 370	−0.3	7 920	8 500	+ 7.3	7 970	+0.6	7 600	7 860	+3.4	7 770	+2.2
240	8 228	8 875	+ 7.9	8 230	0.0	7 720	8 350	+ 8.2	7 830	+1.4	7 360	7 740	+5.2	7 630	+3.7
260	8 086	8 720	+ 7.8	8 100	+0.2	7 640	8 220	+ 7.6	7 700	+0.8	7 200	7 630	+6.0	7 500	+4.2
280	7 958	8 580	+ 7.8	7 990	+0.4	7 510	8 110	+ 8.0	7 590	+1.1	7 040	7 540	+7.1	7 390	+5.0
300	7 842	8 460	+ 7.9	7 890	+0.6	7 380	8 000	+ 8.4	7 490	+1.5	6 900	7 450	+8.0	7 290	+5.6
400	7 423	8 000	+ 7.8	7 500	+1.0	6 900	7 600	+10.1	7 100	+2.9	6 496	7 120	+9.6	6 900	+6.2
500	7 160	7 680	+ 7.3	7 240	+1.1	6 640	7 320	+10.2	6 840	+3.0	6 330	6 900	+9.0	6 640	+4.9
600	6 981	7 450	+ 6.7	7 040	+0.8	6 450	7 120	+10.4	6 640	+2.9	6 220	6 730	+8.2	6 440	+3.5
700	6 846	7 268	+ 6.2	6 890	+0.6	6 330	6 960	+10.0	6 490	+2.5	6 180	6 600	+6.8	6 290	+1.8
800	6 744	7 120	+ 5.6	6 770	+0.4	6 248	6 840	+ 9.5	6 370	+2.0	6 124	6 500	+6.2	6 170	+0.7
900	6 665	7 000	+ 5.0	6 670	+0.1	6 200	6 730	+ 8.5	6 270	+1.1	6 100	6 410	+5.1	6 070	−0.5
1 000	6 600	6 897	+ 4.5	6 580	−0.3	6 170	6 640	+ 7.6	6 180	+0.2	6 080	6 340	+4.3	5 980	−1.6

* *Proceedings*, Am. Soc. C. E., May, 1922, p. 1049.
† *Loc. cit.*, p. 1047.

author. Such a formula might not be quite as simple in appearance as that of the author, but it would be practically as convenient to use. The following is suggested as an alternative to the author's formula, using the same notation:

$$q = 4\,400 + \frac{50\,000}{\sqrt{l_1 + l_2}} - 600 - \frac{l_2 - l_1}{l_2 + 3\,l_1}\left(\begin{array}{c}\text{plus } 3\,000 - 60\,l_2, \text{ for} \\ \text{shears when } l_2 < 50\end{array}\right).$$

This formula reduces to:

$$q = 5\,000 + \frac{50\,000}{\sqrt{l_2}} \text{ (plus } 3\,000 - 60\,l_2, \text{ for } l_2 < 50\text{), for shears;}$$

$$q = 4\,600 + \frac{50\,000}{\sqrt{L}}, \text{ for quarter-span moments;}$$

$$q = 4\,400 + \frac{50\,000}{\sqrt{L}}, \text{ for mid-span moments.}$$

This formula agrees with the composite loading practically as close as the first alternative loading. Table 5 shows the values obtained by the author's formula and by that of the writer, also the percentages of error based on the maximum values of the composite loading. It will be noted that for moments this formula gives a series of curves parallel to the end shear curve. The Cooper loading is different in this respect, as will be seen.

The Cooper E-60 loading can be represented by a similar formula with practically the same degree of accuracy that is shown in Table 5 for the M-60 loading. The general formula is:

$$q = 5\,000 + \frac{30\,000 + 10\,000\,\dfrac{l_2 - l_1}{l_2 + 3\,l_1}}{\sqrt{l_1 + l_2}},$$

which reduces to:

$$q = 5\,000 + \frac{40\,000}{\sqrt{l_2}}, \text{ for shears;}$$

$$q = 5\,000 + \frac{33\,300}{\sqrt{L}}, \text{ for quarter-span moments;}$$

$$q = 5\,000 + \frac{30\,000}{\sqrt{L}}, \text{ for mid-span moments.}$$

The degree of accuracy of this formula may be determined by comparison with Plate XI.*

The author's formula becomes:

$$q = 5\,000 + \frac{60\,000}{\sqrt{l_2}}, \text{ for shears;}$$

$$q = 5\,000 + \frac{52\,000}{\sqrt{L}}, \text{ for quarter-span moments;}$$

$$q = 5\,000 + \frac{42\,400}{\sqrt{L}}, \text{ for mid-span moments.}$$

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* *Proceedings*, Am. Soc. C. E., May, 1922, p. 1047.

It seems likely that any system of loading that may be adopted, can be represented close enough for practical purposes by a general formula similar to that just mentioned.

The author's suggestion in regard to the use of a formula (or charts and tables corresponding thereto), is a valuable one, and is worthy of adoption.

ALBERT LUCIUS,* M. AM. SOC. C. E. (by letter).†—The writer believes the tendency in future bridge loadings will not be toward increased driver axle loads, as the economical limit of rail service is against it, but that the number of drivers will be increased where more traction unit is demanded. He also believes that when electrification of railroads takes place, as sooner or later it will, new motor diagrams will be developed, aiming at a more uniform and equal maximum of motor axle and car axle loads, with a view to reducing maintenance-of-way costs of roadbed and structures.

Referring to the author's request for an expression of preference concerning several alternate propositions for railway bridge loadings in specifications, the writer's preference is as follows: Specify the maximum local axle loads and spacing, the heaviest typical locomotive diagram, and the train load per foot of track.

This expression of preference is without prejudice to the value and correctness of the author's carefully prepared paper and his conclusions and recommendations as contained therein. The writer begs to express his full appreciation of the labor involved and of the service which the author has rendered to the Profession by its publication.

B. A. WORTHINGTON,‡ ESQ., (by letter).§—Relative to the author's suggestion of a wheel loading for locomotives to be used in bridge design to displace the Cooper loading, there is no doubt but that the Cooper loading diagram was scientifically developed, and that at the time it was adopted it was the best and most efficient specification for the locomotives in use. However, the present type of heavy locomotive has outgrown the Cooper loading diagram and the writer thinks the point made by Mr. Steinman is well taken, namely, that the Cooper loading diagram will have to be modified materially if the stresses in railway bridges are to be uniform and no waste in material is to occur.

The importance of making this change is brought out by the author's calculations showing a variation of practically 30 to 40% in stresses, and as a result of his analysis, he suggests three proposed engine loadings.

The writer has studied this matter carefully with the Chief Engineer of the Cincinnati, Indianapolis and Western Railroad Company, H. F. Passel, M. Am. Soc. C. E., and it seems that the first suggestion, namely, "the proposed engine loading (M-60)," would be the most desirable, for the reasons set forth by the author, that this diagram represents the least departure from present practice in bridge design, and it more nearly represents graphically actual conditions.

* Cons. Engr., New York City.

† Received by the Secretary, July 5th, 1922.

‡ Pres., The C. I. & W. R. R., Indianapolis, Ind.

§ Received by the Secretary, July 10th, 1922.

G. H. Gilbert,* Esq. (by letter).†—The author is correct in the claim that the design of railway bridges for E-60 loading does not properly provide for the loading of modern types of engines and the actual axle loads used with such engines. A few years ago, the writer was requested to recommend a bridge loading for new specifications. Although no final recommendations were ever made, some preliminary data were developed, particularly as to the weight of engines in service on the railroads of the United States. The tentative conclusion was that modern locomotive loadings were properly protected by a typical Santa Fé engine with driver axle loads of 65 000 lb., assuming a 20-ft. driver wheel-base and a total wheel-base of 70 ft. of the engine and tender.

The author recommends a loading equivalent to E-75 for short bridges followed, for the longer structures, with a uniform train load of 6 000 lb. per lin. ft. Such a loading is equal to or greater than that of any locomotive now in service. It may be questioned whether railroad executives will approve of such a heavy loading. The Profession and railroad bridge engineers in general, can recommend only such heavy loadings as are in use to any appreciable extent, and such as are indicated by the trend of manufacture, as shown by locomotives built.

As indicated previously, it is considered that an E-60 loading does not properly protect the drivers of Santa Fé engines, nor properly care for the heavy axle loads now being used. Attempts to emphasize such facts are usually met with the claims that the heavy driver axle loads are exceptional and required by the use of special experimental engines or engines designed for special and particular operating requirements, together with the further claim that the Santa Fé type is not necessarily a permanent type and no great number of such engines are in service.

In Table 6, statistics are given, compiled largely from the *Railway Age Gazette,* showing locomotives for use in the United States, as ordered for each year from 1911 to 1921, inclusive. Table 7 gives the variation in weight of the several types of heavy engines, together with the approximate average loading per driver axle. These data would indicate that most of the heavy engines in service have driver axle loads between 55 000 and 65 000 lb.

Table 8 contains data, compiled from special articles, showing heavy driver axle loads. It will be noted that an average driver axle load exceeding 60 000 lb. is common, that this loading is as high as 67 000 lb. for three different orders, and that, in one case, it is as high as 72 400 lb. The last loading and the highest single axle loading of 78 000 lb., are for a single engine.

The recent tendency of locomotive design is toward the increasing use of the Mikado and the Santa Fé types of engine, with little change as regards the use of Mallet engines. The heavy Mountain type of passenger engine is more in demand. This type is virtually an adaptation of the Mikado type for passenger service. On account of the extended wheel-base, its loading, from the standpoint of bridge design, may be neglected, as it will be lighter than the Mikado engine. During the last four years, the data presented show that

* Engr. of Bridges, Southern Ry. System, Lines West, Cincinnati, Ohio.

† Received by the Secretary, July 15th, 1922.

15% of the engines ordered are of the Santa Fé type and that 60% are strictly heavy power, with driver axle loads of from 55 000 to 65 000 lb.

TABLE 6.—LOCOMOTIVES FOR USE IN THE UNITED STATES.
(ORDERED 1911 TO 1917, INCLUSIVE.)

Type.	1911.	1912.	1913.	1914.	1915.	1916.	1917.
Mallet	112	168	72	59	120	218	175
Mikado	590	1 309	796	333	562	754	834
Santa Fé	...	...	...	63	75	325	370
Other types	2 148	3 038	2 599	810	816	1 594	1 345
Total	2 850	4 515	3 467	1 265	1 573	2 891	2 704

(ORDERED 1918 TO 1921, INCLUSIVE.)

Type.	1918.	1919.	1920.	1921.
Mallet	303	1	66	1
Mikado	1 001	11	634	81
Santa Fé	433	...	207	60
Mountain	53	...	69	25
Other types	865	202	795	43
Total for railroad	2 555	214	1 771	210
Total for industries	38	...	227	29
Total	2 593	214	1 998	239

(SUMMARY, 1918 TO 1921, INCLUSIVE.)

Type.	Number.	Percentage.
Mallet	271	5.7
Mikado	1 727	36.4
Santa Fé	700	14.7
Mountain	147	3.1
Other types	1 905	40.1
Total for railroad	4 750	100.0

TABLE 7.—WEIGHTS OF LOCOMOTIVES ORDERED FOR USE IN THE UNITED STATES.

Year ordered.	SANTA FE, 2-10-2.		MALLET, 2-6-6-2.		MALLET, 2-8-8-2.		MALLET, 2-8-8-0	
	Total.	Average driver axle (approx.)	Total.	Average driver axle (approx.)	Total.	Average driver axle (approx.)	Total.	Average driver axle (approx.)
1917.	321 000-411 000	52 000-65 000	420 000-429 000	58 000-59 000	465 000-548 000	51 000-60 000	....	......
1918.	352 000-390 000	58 000-61 000	427 000-440 000	59 000-61 000	540 000-	59 000-	....	......
1920.	361 200-383 000	59 000-60 000	364 000-441 000	49 000-61 000	476 000-494 500	52 000-55 000	494 500	58 500
1921.	378 000-394 100	60 000-62 000	....	....	....	....	505 000	58 000

TABLE 8.—HEAVY DRIVER AXLE LOADS.

Type of locomotive.	Average driver axle load, in pounds.	Highest driver axle load, in pounds.	Driver wheel base.	Authority.
2-10-2.........	62 800	......	22 ft. 10 in.	R. A. G., 12-7-17.
2-10-2.........	67 400	68 800	22 ft. 0 in.	A. R. E. A., *Bulletin No. 223.*
2-10-2.........	58 600	60 000	20 ft. 7 in.	C. N. O. & T. P. Ry.
2-10-2.........	67 500	......	22 ft. 6 in.	R. A. G., 8-3-17.
2-10-2.........	72 400	78 000	22 ft. 2 in.	A. R. E. A., *Bulletin No. 223.*
2-10-0.........	66 900	......	22 ft. 8 in.	R. A. G., 6-15-17.
0-8-8-0........	58 300	59 400	40 ft. 3½ in.	A. R. E. A., *Bulletin No. 223.*
2-8-8-0........	57 800	......	41 ft. 2 in.	R. A. G., 7-28-16.
2-8-8-2........	59 000	......	42 ft. 1 in.	R. A. G., 7-12-18.
2-8-8-2........	60 100	61 800	42 ft. 1 in.	A. R. E. A., *Bulletin No. 223.*
2-8-8-2........	58 400	......	42 ft. 0 in.	R. A. G., 8-15-19.
2-8-2..........	63 800	65 500	16 ft. 0 in.	L. & N. R. R.
2-8-2..........	63 000	64 800	16 ft. 6 in.	A. R. E. A., *Bulletin No. 223.*
2-10-10-2......	60 000	60 000	50 ft. 5 in.	A. R. E. A., *Bulletin No. 223.*
2-8-8-8-4......	60 500	......	67 ft. 7 in.	R. A. G., 1-26-17.

It appears obvious to the writer that, in selecting a proper bridge loading, the Santa Fé type can no more be ignored than any other type of engine. If that fact is once granted, it follows that many short spans and the floor systems of the through spans designed for E-60 loading will, at unit stresses, only take the Santa Fé engines when the driver axle loads are reduced to about 53 000 or 54 000 lb. The tendency of driver axle loading is the reverse. A railroad using 60 000-lb. axle loads, with the old type of engines, such as the Consolidation, is forced by the need of tractive power to use 63 000 to 66 000 lb. for axle loads of its Mikado and Santa Fé engines.

In considering a broad matter like bridge building, affecting the development of railroads for the next 15 or 20 years, it is well to keep close to fundamentals. The types and weights which have developed within the last 10 years are due to an ever-increasing demand for tractive power. For passenger engines and freight engines of the Mikado type, there is the added demand of speed. The Santa Fé and Mallet types are probably restricted to use with drag freights, and the Mikado engine is the most popular freight engine. The use of a trailer develops the full value of the weight on the four drivers, so that in the future any increased tractive power must be obtained either by increasing the weights on the drivers, or by changing the type of engine. From some standpoints, the change to a Santa Fé or Mallet type is objectionable, so that fundamentally it seems reasonable that during the next few years there will be an increase in the weight of driver axles on the Mikado type of engine. Some railroads already are using about 64 000 lb. per driver.

To obtain tractive power greater than that afforded by the Mikado, it is necessary to use more driver axles. This leads immediately to the 5-axle or Santa Fé engine, or the Mallet engine with its 6, 7, 8, or even 10 axles.

The extended wheel-base used with Mallet engines greatly reduces the bridge loading when compared with the E-60 loading. For floor systems and short spans, there is no such reduction with the 5-driver axle, or Santa Fé type.

In studying this matter a few years ago, the writer compiled the diagrams, shown on Fig. 13, which compare moment, shear, and floor-beam reactions for the following locomotives:

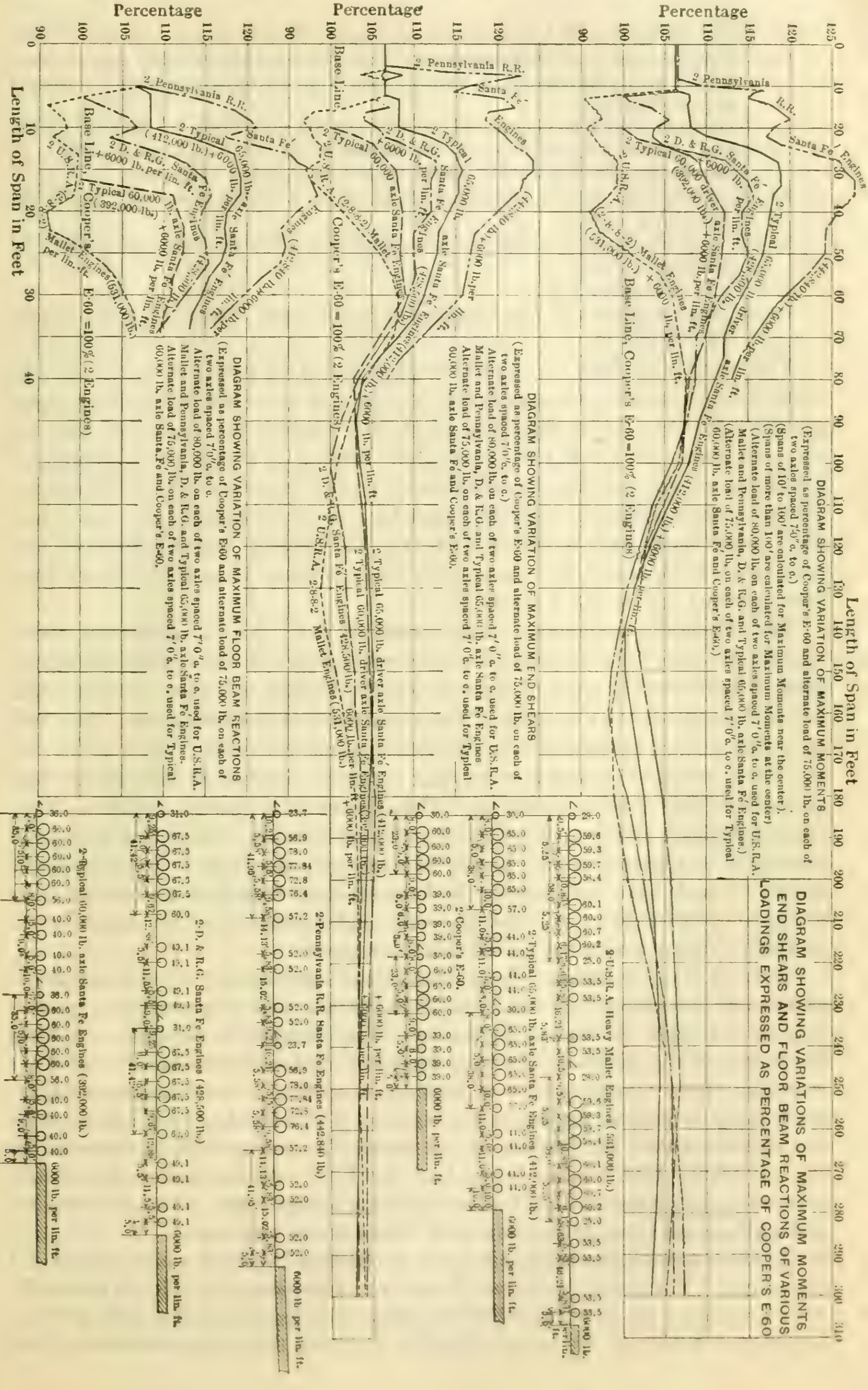
DIAGRAM SHOWING VARIATIONS OF MAXIMUM MOMENTS END SHEARS AND FLOOR BEAM REACTIONS OF VARIOUS LOADINGS EXPRESSED AS PERCENTAGE OF COOPER'S E-60
DIAGRAM SHOWING VARIATION OF MAXIMUM MOMENTS
DIAGRAM SHOWING VARIATION OF MAXIMUM END SHEARS
DIAGRAM SHOWING VARIATION OF MAXIMUM FLOOR BEAM REACTIONS
Percentage
Length of Span in Feet
Base Line, Cooper's E-60 = 100% (2 Engines)
2 Pennsylvania R.R.
2 Typical 60,000 lb. axle Santa Fe Engines (392,000 lb.)
2 D. & R.G. Santa Fe Engines (428,500 lb.)
2-Pennsylvania R.R. Santa Fe Engines (442,840 lb.)
2-Cooper's E-60.
2-Typical 65,000 lb. axle Santa Fe Engines (412,000 lb.)
2-U.S.R.A. Heavy Mallet Engines (631,000 lb.)
6000 lb. per lin. ft.

FIG. 13.

1.—A U. S. Railroad Administration, heavy, Mallet engine of the 2-8-8-2 type, assumed as representing about the heaviest Mallet engine that would be used, except at special locations to meet peculiar operating requirements.

2.—A Denver and Rio Grande Santa Fé engine weighing 428 500 lb. This was assumed as typical of the heaviest Santa Fé engines built. It should be noted that the wheel-base is somewhat extended.

3.—A typical Santa Fé engine with condensed wheel-base and 65 000 lb. per driver axle.

4.—A typical Santa Fé engine with condensed wheel-base and 60 000 lb. per driver axle.

5.—An E-60 loading.

6.—A special engine of the Pennsylvania Railroad, Santa Fé type, weighing 442 840 lb.

The plotting of data for the last engine was of no practical value. It was interesting as showing the percentage by which it exceeds other loadings more generally in use. These diagrams (Fig. 13), support the statement that for spans in excess of about 100 ft., an E-60 loading is about heavy enough, as far as trusses are concerned, regardless of type of engine or weight of drivers. However, these diagrams also show that for a concentration of five axles on a 20-ft. wheel-base, with 65 000 lb. per axle, the loading demand for floor systems of all bridges and for many short spans is from 15 to 20% greater than that provided for by the E-60 design.

Five 65 000-lb. driver axle loads, spaced at 5 ft., with a condensed wheel-base for the entire locomotive and tender, will protect all the engines commonly used. Under certain types of locomotives, the loading will give extra strength in the floor system and hangers of truss bridges, and in short spans. This will give only needed protection to such metal against corrosion. Even if the life of a steel bridge is assumed to be only 30 years, the loss of strength of floor systems in that time is alarming. The menace of corrosion, resulting from brine drippings, and from a policy of paint maintenance controlled by the net income of a railroad, would justify the use of reduced unit stresses in the design of such parts. Certainly, it demands that floor systems be originally designed so that they will not be weak under engines which represent 15 to 25% of those purchased in the last four years.

Regardless of criticism of the heavy loading proposed by the author, it appears to be self-evident that the E-60 designs are outgrown as a protection to the types of engines in service. The Committee on Iron and Steel Structures of the American Railway Engineering Association has defended the retention of the Cooper system of loading, in spite of representations as to its inadequacy to protect the Santa Fé engines. Criticism has been answered by the statement that the loading of the Santa Fé engines will be protected by the use of the E-65 loading instead of the E-60. As the author has clearly pointed out, this results in a loading for long bridge spans, which is excessive, and an increase in uniform train load, which is not warranted.

A fundamental psychological factor is further involved which should not be ignored. For years, executive officers, and transportation officials generally, have associated the E-50 and E-60 loadings with corresponding axle loads of 50 000 and 60 000 lb. It is unreasonable to expect that such executive officers

will understand and approve a loading called the E-65, which does not protect axle loads of 65 000 lb. Further, it is extremely difficult to obtain the approval of expenditures when the implied loading is decidedly greater than the axle loading of the engines in use, or those likely to be purchased.

Railroad officials generally are being educated to the fact that new bridges designed for ordinary unit stresses have a factor of safety sufficient to allow the operation of any type of engine or weight of driver axle. Such officials, naturally, cannot be expected to be particularly interested in consistency of design which will permit a proportional increase of axle load for all types of engines operated. It is the function of the Profession, and railroad bridge engineers, in particular, to recommend such loading as will be consistent for all types of power which are likely to be operated and which, at the same time, will appeal to financial and executive officials as properly conservative and based on axle loads of modern heavy power.

It is to be hoped that, in the discussion of this paper, criticism of the extreme high loading which the author recommends shall not be allowed to cloud the essential facts which he has so ably presented, namely, the inadequacy of the Cooper system of loading at ordinary unit stresses of design properly to care for the present engine loading and for such engine loading as may reasonably be expected in the next 5 or 10 years.

J. A. L. Waddell,* M. Am. Soc. C. E. (by letter).†—The evolution in America of bridge designing during the last four decades has been marked from time to time by certain epoch-making papers, usually presented to the Society and thoroughly discussed by its members. To these papers and their discussions is mainly due the development of bridgework from a crude art to an advanced science.

This paper is worthy of being included in the list of such epoch-making papers. The Society and the Profession are deeply indebted to the author for his praiseworthy altruism in undertaking such an important investigation. The writer, for the last forty years, has been making somewhat similar studies. As long ago as 1892, in a paper entitled, "Some Disputed Points in Railway Bridge Designing",‡ he treated at considerable length the subjects of railway bridge loadings and equivalent uniform live loads. Following the publication of that paper, he extended his investigations, and, later, wrote a pamphlet entitled "The Compromise Standard System of Live Loads for Railway Bridges and the Equivalents for Same." This pamphlet evoked much discussion in the technical press, as some engineers were opposed to the use of equivalent loadings, deeming exactness of stresses to be a *sine qua non*, and seeming to forget that all assumed loadings are merely typical and that they will never be more than approximately realized.

The result of the original papers and the ensuing numerous (and often quite warm) discussions was eventually to bring into general use the simple and economic method of calculating live load stresses in bridges by the use

* Cons. Engr., New York City.

† Received by the Secretary, July 19th, 1922.

‡ *Transactions*, Am. Soc. C. E., Vol. XXVI (1892), p. 77.

of equivalent uniform loads. In those days, that method was much more accurate than it is at present—for three reasons:

First.—Both the maximum and the average span lengths were then much shorter than they are now.

Second.—The weight per linear foot of the locomotives with their tenders did not then greatly exceed the weight per linear foot of the loaded cars, whereas, to-day, the excess is 50% or more.

Third.—The modern locomotives are longer than those in use three decades ago.

It goes without saying that the greater the excess of locomotive weight, as compared with that of a corresponding length of loaded cars, the greater will be the variations of stresses computed by the two systems—wheel loadings and equivalent uniform loads.

Comparing Mr. Steinman's investigation with that of the writer previously mentioned, there is as great a variation between them, in respect both to importance and science of treatment, as there is in the weights of present-day locomotives and those of that time.

The author has shown that the "Cooper" loadings should be relegated to oblivion; and, in the writer's opinion, the proposed new system is as good as can be evolved for the purpose of bridge designing. The argument suggested as a reason for retaining the Cooper loading, namely, "that it affords a convenient standard for rating bridges", is unsound, because the author's M-60 loading, with its proportionate M-10 unit loading, provides just as convenient a rating standard.

The "rating standard" evolved by Charles F. Loweth, M. Am. Soc. C. E., deserves to be considered as one of the "epoch-making" investigations in the evolution of bridgework, notwithstanding the fact that it is disassociated from designing.

Concerning the author's three suggested loadings, the writer is opposed to Loading No. 2 as being unscientific and illogical. It has no real *raison d'être*, for it is much more troublesome to use than the equivalent-uniform-load method, and but little, if any, more accurate.

As for Loading No. 1, it is well to retain it and include it in the specifications as the typical wheel loading, but it should be clearly stated therein that it is not to be used in computing stresses.

Loading No. 3 is by far the best, and should be generally adopted. As stated by the author, it is "the most scientific in principle and most convenient in application." In the writer's opinion, this claim cannot be gainsaid.

The specifying of a live load shown by wheel diagram and using instead a loading indicated by a formula that agrees therewith only approximately may be objectionable to some engineers; but what does it matter if there is an occasional difference of a few per cent. between the two methods when both of them are merely arbitrary assumptions? To overcome this objection and satisfy the quibblers, let the formula be called the true standard and the wheel diagram its approximate graphic representation.

The thoroughness of the author's investigation and the clearness of his presentation of findings mark this paper as one of the best ever submitted to the Society.

GUSTAV LINDENTHAL,* M. AM. SOC. C. E. (by letter).†—The author's painstaking analysis of the different locomotive loadings in use for the design of American railroad bridges is a valuable contribution to a subject which has been discussed for a long time, but which is not as vexing as is usually assumed.

The Cooper standard has become conventional, because it is sufficiently inclusive of maximum effects from concentrated loadings of locomotives and the grouping of such loadings. When locomotives become heavier, it is convenient to assume heavier axle loads without disturbing the grouping. Some locomotive axle loads have already reached nearly 80 000 lb. and some groupings of wheel loads, 370 000 lb. in 22 ft. There may be further increases in loads and changes in wheel-spacing that cannot be foreseen. At times, bridges have to carry whole trains of dead locomotives. Meticulous accuracy, therefore, is out of place.

The author's proposed first method, substituting a new and simpler wheel-load diagram for the Cooper diagram, seems preferable to his other two proposed methods. It would represent the smallest departure from present methods and is sufficiently inclusive of the maximum effects of loads from any of the seven locomotive-wheel diagrams illustrated in his paper. The Cooper diagram should also be illustrated in this paper, so that bridge engineers of other countries may know without searching elsewhere what the Cooper E-60 loading represents. Trusses in longer spans are less affected by the heavier locomotives than those of shorter spans, as may also be seen from the author's Figs. 6 and 9.‡

The floor construction is merely a succession of short spans, therefore, it suffers more than the trusses from an increase of locomotive weights. The larger allowance for impact in floor members covers, to a certain extent, unforeseen increases in wheel loads.

Fast trains which produce the largest impact stresses, usually have lighter locomotives. The heavy locomotives considered by the author are used only with freight trains, usually at only one-half the speed of passenger trains, therefore, smaller impact stresses are produced. It is probable that heavy axle loads plus impact produce smaller stresses than the lighter passenger locomotives plus impact, at 50 to 60 miles per hour.

R. A. CAUGHEY,§ M. AM. SOC. C. E. (by letter).‖—The writer believes that Mr. Steinman has made a wonderful contribution to the Profession in the preparation of his paper and has done a great deal toward making changes in loadings for railway bridges which many engineers have recognized as necessary, but have been unable to suggest on account of the enormous amount of work involved. He has proved that the Cooper loading should be replaced by

* Cons. Engr., New York City.

† Received by the Secretary, July 19th, 1922.

‡ *Proceedings*, Am. Soc. C. E., May, 1922, pp. 1059 and 1063.

§ Associate Prof., Structural Eng., Iowa State Coll., Ames, Iowa.

‖ Received by the Secretary, July 19th, 1922.

one more in accordance with the weights and axle arrangements of modern railway rolling stock. He has also developed an equivalent uniform load which is really "equivalent", as he has taken into account the position of the section at which shear or moment is desired. Perhaps, it would be more accurate to say that three systems of equivalent loading have been developed, giving design results far more satisfactory than those of the Cooper system.

As to which of these systems it would be best to adopt, the writer would favor the first, the M engine diagram, and might be criticized for doing so, as it would seem that either of the last two loadings would be easier to apply. This would be true under ordinary circumstances, but with a chart available, such as is given by the author on Plate XVII,* and a table of equivalent uniform loads, such as that given in Fig. 2,† no one who dislikes the long computations involved in stresses due to wheel loads would be forced to make them.

In many cases, the position of engine loading (even though hypothetical) on the structure is desired and of the three schemes suggested the first is the only one which would give this. One case in which such information would be desired would be that of a complicated structure having a broken influence line some segments of which would represent positive and others negative stress and in which the maximum stress would have to be determined by trial positions of the engine and train.

Another point in favor of the engine diagram, the writer believes, is that it keeps the computer more in touch with the principles involved in the computation of stresses due to moving loads; and it is his belief that the engineer who computes stresses without an understanding of the underlying principles is of little use to his employer. If the first method was in vogue, any computer would have the equivalent load as a time-saver and still not lose sight of the loading producing it.

The officials of some roads prefer to use their own engine diagrams in the design of bridges, and no doubt they would find the engine diagram closer to the conditions with which they deal and could use it best as a basis of comparison with their loadings. In such cases, the engine diagram would be the basis for "short cuts" such as equivalent uniform load charts and tables, and it would seem that it should be and could be so in the case of the M loadings.

To sum up, it is the writer's belief that a change in bridge loadings should be made and that a simple, tangible system should be adopted. Much could be said for the simplicity of the third method, but it is a question as to whether railway bridge designers would care to think of a bridge loading as a thing so intangible as to be represented by an equation, and it may also be noticed on investigation that, for certain conditions, there is considerable variation from the "composite" loading when the equation is used. It seems that by the use of the author's charts, tables, etc., the first method will satisfy all requirements of simplicity and tangibility, will give a loading approximating most closely the "composite" loading, and, in addition, will be easy to use in bridge specifications.

* *Proceedings*, Am. Soc. C. E., May, 1922, p. 1059.

† *Loc. cit.*, p. 1053.

While on the subject of railway bridge loadings, the writer wishes to state that, on branch roads, the controlling load in the design of bridges, especially short-span bridges, is the train load instead of the engine. To illustrate this, compute the maximum live load bending moment at the center of a 40-ft. plate girder span, the traffic on which consists of an engine load followed by Pennsylvania railroad gondola cars of 220 000 lb. capacity, with an allowance of 10% for overload. The weight of these cars is 74 600 lb. It will be assumed that the engine is equivalent to Cooper's E-50. According to the author's Table 3,* a Cooper's E-64 engine is equivalent to an M-50 loading when the center moment on a 40-ft. beam is considered. An E-50 engine, therefore, would be equivalent to $\frac{50}{64} \times 50 = 39$, say M-40. The center moment due to a train of the coal cars mentioned will exceed nearly 15% that of the M-40 engine loading. From this, it would seem that attention should be given to this type of loading as well as to locomotive loading, especially when light locomotives are used.

J. C. RALSTON,† M. AM. SOC. C. E. (by letter).‡—The author's paper embodies a comprehensive if not a conclusive re-cast of a question which heretofore has been in a state of general flux. As a comparative study, with a re-valuation of the essential factors, lighted by the last word of the mechanical or motive power engineer, and evaluated by the theory of probabilities in future locomotive development, it is likely to clarify and standardize future specifications on loadings for many years.

Viewing the paper from the human standpoint of ethical ambition on the part of the author, it is expressive of the best devotional spirit of the Profession. Too often this spirit of contribution is lost sight of by the reviewer who would apply his own yard-stick in measuring engineering worth. Happily, this paper is timely, because it is serviceable in a practical way.

The redemption and the inspiration of the Profession lie in the contribution of a definite, usable, and needed technical asset. When such contributions are inspired by altruistic vision rather than profit, the genius of a great profession is finding its most lofty expression.

It is in this larger sense that the writer would commend the author. He has shown the erratics of the Cooper applications, or, as he states, "smoothed out the depressions," and given the bridge designer a more consistent and logical procedure for the determination of his controlling stresses.

It is safe to assume that the equivalent uniform loadings, applied either directly or through the author's so-called Composite, will stand for a long time.

The engineering offices of the motive power departments generally are turning their attention to the details of boiler and cylinder performances, to the metallurgy and the re-design of revolving and reciprocating parts, and to special devices, rather than to any further increase in or multiplication of axle concentrations. Road structures and clearances are putting a peremptory estoppel on further swelling the bulk dimensions of locomotives. Mechanical

* *Proceedings*, Am. Soc. C. E., May, 1922, p. 1061.

† Cons. Engr., Spokane, Wash.

‡ Received by the Secretary, July 22d, 1922.

and energic improvements of locomotives have been delayed too long, but the obsession is now and will be toward carrying them to maximum finality.

The ratios between heating surfaces, grate areas, and cylinder volumes have been digested and re-digested carefully. At present, and hereafter, the mandatory is on that of providing a gas to produce the greatest cylinder horsepower and of obtaining greater calorific results per cubic foot of firebox volume. Pyramiding further axle concentrations on top of obsolete steaming practice is in limbo. These considerations being true, the railway bridge designer may look forward with confidence to an extended period for the application of the author's thesis.

Railway engineering has not been confined to the bold projects of territorial penetration, nor to the conquest of rugged and intransitable gorges, but covers also those masterful exploits which the patience, ingenuity, and genius of the mechanical engineer and the bridge engineer have accomplished. It has been an Augustan Age from the days of "Puffing Billy", the grass-hopper locomotive, to this hour of the super-Mallet and its concomitants, the colossal cantilever or the awe-inspiring arch. The "Rocket" locomotive of 1830, weighing 4¼ tons, and the "Old Ironsides" of 1832, weighing 5½ tons, were feeble but epochal beginnings. Ten years later, the pace had been trebled. In 1842, Matthias Baldwin built for the Georgia Railroad, on order from J. Edgar Thomson, its Chief Engineer, fourteen of those famous "6-wheels-connected" locomotives. They weighed 12 tons each, or 4 tons per axle. Messrs. Thomson, Latrobe, and others of those days, and, later, Meigs, Fink, Bollman, Howe, and their contemporaries were marking great strides in bridge design. Yet the work of each, has become obsolete and inadequate practice. Newer and better engines and stronger and bigger bridges were demanded. Within the last decade, the bridge designer must draw his specifications for the requirements of locomotives with two and even three groups of drivers, each engaging four or five axles under concentrations of 60, 70, or 80 tons, and some ponderous machines weighed as much as 449 tons—one hundred times more than the original locomotive.

J. C. Bland,* M. Am. Soc. C. E. (by letter).†—In the Cooper specifications of 1890, the two heaviest loadings used were the "Lehigh Heavy Grade Engine Class" and "Class Extra Heavy A". Each loading consisted of two coupled Consolidation engines followed by a train designated as so many pounds per linear foot of track. Each engine was 32 ft. 7 in. long, with a tender 20 ft. 10 in. long.

The "Lehigh Heavy Grade" engine weighed as follows:

Pony truck	16 000 lb.
4 driver axles, at 40 000 lb.	160 000 "
2 tender axles, at 18 000 lb.	36 000 "
2 " " , at 20 000 lb.	40 000 "
Total	252 000 lb.

The train load was 4 000 lb. per lin. ft.

* Engr. of Bridges and Bldgs., Pennsylvania System, Pittsburgh, Pa.

† Received by the Secretary, July 22d, 1922.

The "Class Extra Heavy A" weighed as follows:

Pony truck	16 000 lb.
4 driver axles, at 30 000 lb.	120 000 "
4 tender axles, at 18 000 lb.	72 000 "
Total	208 000 lb.

The train load was 3 000 lb. per lin. ft.

In 1894, Cooper in his paper entitled, "Train Loadings for Railway Bridges",* proposed the loading which since has been so generally used. This loading consisted of two coupled Consolidation engines, the length of the engine being 34 ft. and that of the tender, 22 ft. The train load was given as so many pounds per linear foot of track.

In this loading, the various axle loads were expressed in terms of the driver axle load considered as unity, that is, the pony truck axle load was 0.5; each of the four driver axles was 1.0; and each of the four tender axle loads was 0.65. Thus, the weight of the engine was 4.50 units; that of the tender 2.60 units, and the train weight per linear foot was 0.10 units. Cooper gave as a minimum the E-25, and as a maximum the E-40, loading. He seemed to have considered the latter the heaviest loading possible, and expressly said so regarding the train load of 4 000 lb. per lin. ft.

When the axle loads increased between the limits named, there was no change in the axle spacing, therefore, computing moments, shear, etc., for unit loads for this axle spacing, the finding of these functions for any E loading was merely a matter of multiplication.

The advantages of this loading are many, but the disadvantages are:

(1).—That even in 1894, the ratio of tender axle load to driver axle load of 0.65 was smaller than that in actual engines; and the distance between the rear driver axle and front tender axle of 9 ft. was 30% less than in actual engines of the Consolidation type.

(2).—The weight of the train per linear foot was given as one-tenth the driver axle load, that is, the train load is a fixed proportion of the driver axle load.

(3).—The method was clearly inapplicable to engines of a type different from that assumed, namely, the Consolidation type.

As the weight of engines of the same type increases, the wheel-base and length increase, and although this is of not much account between the limits given by Cooper in 1894 for his proposed loading (namely, from E-25 to E-40), it becomes of consequence beyond E-40. In short, the E loading is not applicable beyond Cooper's upper limit.

As to the train, there is no necessary relation between the weight of train per linear foot and the driver axle load, or, more generally, the weight on the driver axles. The gross weight of the train as a whole depends on the tractive power, and that again depends on the load on the drivers. Within the limits of the Cooper proposed loading of 1894 (E-25 to E-40), this did not make much difference, as E-40 engines were generally hauling 4 000-lb. trains, but the principle cannot be extended to E-60 engines or greater.

* *Transactions*, Am. Soc. C. E., Vol. XXXI (1894), p. 174.

In his paper, previously mentioned, Cooper wisely remarks that "the tendency to seek for a 'final standard' in any engineering construction, regardless of changing conditions, is a harmful one," and, by the same token, the writer considers that for many years the "Cooper loading" has ceased to be a standard. He concurs with the author when he states that "the time has come to make a fresh start, with a system based on the existing locomotive and train loads", and the writer feels confident, that if Mr. Cooper was still alive, he would share this view and be among the first to devise a new method and one which not only conformed to existing engines and train loads, but looked forward and beyond. The author's paper is so complete as to leave little room for discussion.

The writer studied the effects of some of the heaviest engines and train loads of the Pennsylvania System, and prepared a diagram which showed the "Cooper index" or "equivalent" for each foot of span up to 300 ft., for bending moments, shears, and cross-girder re-actions. The great variation of the "Index" for the same engine fully exhibits the inadequacy of the "Cooper loading" to represent the stress effects of modern heavy engines and trains. Table 9 gives the principal data for the heavy engines of the Pennsylvania System, as compared with the Cooper E-60.

Apparently, Cooper did not look forward to the use of engines other than those of the Consolidation (2-8-0) type, and the data given for the heaviest engine of that type used on the Pennsylvania System (the H-10-s), shows the great difference in many of the ratios, which, on the supposition of extending the Cooper system of loading beyond the E-40 given in his paper previously mentioned, should be the same.

The H-10-s engine has a Cooper equivalent or index of E-55 to E-50, and being of the Consolidation type, naturally shows less variation in the index than the engines of different types. Nevertheless, there are wide divergences in the ratios. The Cooper engine weighs 7.10 times the driver axle load, whereas the H-10-s weighs 7.61 times the mean axle load. The Cooper tender weighs 2.60 times the driver axle load, whereas the tender of the H-10-s weighs 3.18 times the mean driver axle load, or, differently expressed, the Cooper tender axle load is 65% of the driver axle load, whereas the H-10-s tender axle load is 79.6% of the mean driver axle load.

It would be hardly fair to dwell on the divergences of the ratios of engines of other types from the Cooper ratios. One could scarcely expect to find a Consolidation engine of the Cooper type, which would produce the same stress effects as those caused by such an engine as the N-1-s; therefore, it is here that the author's suggested loading seems to fulfill the requirements. He makes a "composite" of all the heavy engines, and finds a loading which will come measurably close to the moments, shears, etc., caused by this "composite"; thus, all the irregularities of the actual engines are eliminated. Of the three forms of loading presented by Mr. Steinman for replacing the Cooper E loading, the writer much prefers the third.

The Cooper loading has been of incalculable service, not indeed for the design of bridges, but for expressing the capacity of existing bridges. It has furnished a base, now fully understood by railroad men, whereby structures

TABLE 9.—COMPARISON OF PENNSYLVANIA SYSTEM HEAVY FREIGHT ENGINES.

	Consolidation, 2-8-0	Consolidation, 2-8-0	Mikado, 2-8-2	Santa Fe, 2-10-2	Santa Fe, 2-10-2	Decapod, 2-10-0	Mallet, 0-8-8-0	Mallet, 2-8-8-0
Class of engine	E-60	H-10-s	L-1-s	N-2-s	N-1-s	I-1-s	C-C-2-s	H-C-1-s
Type of engine	2-8-0	2-8-0	2-8-2	2-10-2	2-10-2	2-10-0	0-8-8-0	2-8-8-0
Weight of engine, in pounds	270 000.	255 800.	335 100.	380 000.	435 000.	371 000.	460 000.	619 200.
Weight of tender, in pounds	156 000.	184 000.	191 300.	207 800.	207 000.	182 400.	210 000.	244 800.
Total weight, engine and tender, in pounds	426 000.	439 800.	526 400.	587 800.	642 000.	553 400.	670 000.	864 000.
Length of engine, in feet	34.0	40.7	50.0	56.0	57.2	49 6	59.3	70.0
Length of tender, in feet	22.0	30.9	32.2	37.4	34.0	32.2	34.0	34.0
Total length, engine and tender, in feet	56.0	71.6	82.2	93.4	91.2	81.8	93.3	104.0
Weight of engine, in pounds per linear foot	7 941.	6 285.	6 702.	6 786.	7 605.	7 480.	7 757.	8 845.
Weight of tender, in pounds per linear foot	7 091.	5 954.	5 941.	5 557.	3 088.	5 664.	6 177.	7 200.
Weight of engine and tender, in pounds per linear foot	7 607.	6 142.	6 404.	6 293.	7 039.	6 765.	7 181.	8 308.
Weight on driver axles, in pounds	240 000.	231 300.	253 500.	298 000.	341 000.	327 000.	460 000.	583 000.
Number of driver axles, and diameter, in inches	4.	4 62	4-62	5-63	5-62	5-62	8-51	8-62
Mean weight on each driver axle, in pounds	60 000.	57 800.	63 400.	58 600.	68 200.	65 400.	57 500.	72 900.
Maximum weight on driver axle, in pounds	60 000.	62 000.	72 560.	60 600.	75 600.	68 000.	62 000.	86 400.
Tractive power, in pounds	......	205	205	190	215	250	225	205
Boiler pressure, in pounds per square inch	60 000.	53 200.	61 500.	74 000.	85 000.	90 000.	91 000.	130 500.
Ratio of weight on drivers to tractive power	4.0	4.33	4.12	3.96	4.13	3.63	4.0	4.46
Ratio of tractive power to weight on drivers	0.25	0.231	0.243	0.253	0.242	0.275	0.250	0.224
Tender axle load, in pounds	39 000.	46 000.	47 825.	51 950.	51 750.	45 600.	52 500.	61 200.
Ratio of tender axle load to mean driver axle load	0.65	0.796	0.754	0.886	0.759	0.697	0.913	0.839
Ratio of length of tender to length of engine	0.647	0.7592	0.644	0.668	0.591	0.649	0.573	0.486
Ratio of length of engine to total length of engine and tender	0.607	0.568	0.608	0.60	0.616	0.606	0.636	0.673 8.49
Ratio of weight of engine to mean driver axle load	4.50	4.43	5.29	6.48	6.38	5.67	8.0	
Ratio of weight of tender to mean driver axle load	2.60	3.18	3.02	3.55	3.04	2.79	3.65	3.36
Ratio of weight of engine and tender to mean driver axle load	7.10	7.61	8.30	10.03	9.41	8.46	11.65	11.85
Ratio of weight per linear foot of engine and tender to mean driver axle load	0.1268	0.1063	0.1010	0.1074	0.1032	0.1034	0.1249	0.1139
Ratio of weight of engine to tractive power	4.50	4.81	5.45	5.14	5.12	4.12	5.06	4.74
Ratio of weight of engine and tender to tractive power	7.10	8.27	8.56	7.94	7.55	6.15	7.36	6.62
H-21-cars, marked capacity in pounds	140 000.; overload 10%; weight 56 000 lb.; length 44 ft.; weight per linear foot of train = 4 773 lb.							
G-23-cars, marked capacity in pounds	220 000.; overload 10%; weight 86 000 lb.; length 54 ft.; weight per linear foot of train = 6 000 lb.							
Ratio of weight per foot, H-21-train, to mean driver axle load	0.0795	0.0826	0.0753	0.0814	0.0699	0.0729	0.0830	0.0655
Ratio of weight per foot, G-23-train, to mean driver axle load	0.10	0.1038	0.0946	0.1024	0.088	0.0917	0.1023	0.0823

NOTE—Tractive power for mean effective pressure, = 85% of the boiler pressure, except in cases of the I-1-s and the H-C-1-s. For the I-1-s, the tractive power = 75% of the boiler pressure, and for the H-C-1-s, it is based on weight on drivers.

may be classified and compared. By taking an actual engine and determining the stresses in each member of an existing structure, and then by dividing each stress, moment, or shear, etc., by those due to the Cooper E-1, the Cooper index for each member is obtained, the lowest of which gives the capacity of the bridge. Any other typical engine would do as a base, but the Cooper engine serves the purpose far better, principally because of its general acceptance.

With the introduction, some years later, of engines with trailers, and also of engines of the Mallet type, the use of Consolidation engines for the design of bridges could hardly be maintained as good practice, and such railroads as had adopted the Cooper loadings as their standard were soon compelled to use different Cooper loadings for the different parts of the same bridge, as is pointed out by the author. Such a practice is not desirable.

The defects of the Cooper loading for the design of bridges having been so clearly shown by Mr. Steinman, the writer hopes that one of the three methods presented will soon be adopted by the Profession. The writer earnestly desires the abandonment of the Cooper loading for the design of new bridges of a capacity greater than E-40, but he has no such wish with reference to its use in stating the maximum capacity of existing structures; in short, the Cooper loading should still be maintained for use as the base of reference.

With reference to the design of structures, the writer wishes that each railroad would consider the group of its engines for which it wishes to provide, form a "composite" of such engines, and then choose the M loading (taking into account future development) that best fits its case, and use such loading in its specifications.

"Taking into account future developments," stated previously, presents a problem. Shall a given percentage be added to each of the engines forming the "composite"? Or, shall only those of the group which one thinks will in time be increased be considered? The easy way would be to increase each one of the group by a given percentage—the better way is to consider the question further. The Mikado engine is a Consolidation engine with an added axle—the trailer—which in a sense may be called non-productive weight, as it does not increase the adhesion of the drivers. In the I-1-s engine, however, the added axle is a driver, and, therefore, the adhesion is increased.

Comparing the L-1-s engine with its predecessor the H-10-s, the weight on the drivers was increased only 9½%, while the weight of the engine increased 32%, and the tractive power increased only 16 per cent. Comparing the I-1-s engine with the H-10-s, the weight on the drivers increased 41%, and the weight of the engine increased 45%, whereas the tractive power increased 69 per cent. The I-1-s would seem a better and more economical development than the L-1-s.

Again, compare the N-1-s with the H-10-s. The weight on the drivers increased 47%; the weight of the engine increased 70%; and the tractive power increased 60 per cent. This does not seem as economical a development as the I-1-s, and although the I-1-s weighs 96% of the N-1-s, its tractive power is 6% greater, and the weight of engine per pound of tractive power

is 4.12 as against 5.12 for the N-1-s; that is, a pound weight of the I-1-s is more productive than a pound weight of the N-1-s.

Thus, it would seem that the I-1-s type of engine was more likely to be increased in the future than the L-1-s or N-1-s types.

The stress effects of the I-1-s type do not differ much from those of the N-1-s; therefore, it is immaterial if both were increased in the same proportion. Prognosis as to engine development, however, is extremely hazardous, the writer merely presents the facts as they stand to-day and ventures a few comments.

J. M. Johnson,* M. Am. Soc. C. E. (by letter).†—The author presents, in a convincing manner, the defects of the Cooper system of rating as applied to many of the present-day locomotives. The writer agrees with this indictment, if it is confined to those roads having a heavy and steady tonnage, consisting principally of coal, ore, and furnace products, requiring for its economical movement, under diverse conditions, the various locomotives (seven in number) tabulated by the author. For such roads, the Cooper rating fails, or is unsatisfactory, and could be replaced with advantage by the author's system, based on any one of the three proposed loadings.

There is, however, a large mileage in the South, Southwest, and parts of the West, constructed, of necessity, originally with a large curvature and with comparatively light rail. Also, from necessity, this condition is likely to remain practically unchanged for some time. On many of the roads in this territory, the heaviest power is of the Mikado and Mountain types of locomotives, the curves (shear and moment) of which agree quite closely with the Consolidated type of equal axle loads, and, in consequence, the Cooper loading gives satisfactory working results. On other roads of the same region, in addition to the Mikado and Mountain types, 2-10-2 locomotives with maximum axle loads of about 60 000 lb. are in use on divisions where the curves are not too sharp. The shear and moment curves of this engine, for equal axle loads, are somewhat above the Cooper curves, but the difference between the curves when only one 2-10-2 locomotive is used, is not marked, except for short spans. Engines heavier than the three types mentioned would have no place on these roads, except that occasionally a locomotive of the Mallet type is used as a pusher on a mountain grade.

C. D. Purdon, M. Am. Soc. C. E. investigated the relation between the Cooper loading, and various heavy locomotives, with axle loads averaging 55 000 lb. The result of this investigation is shown by curves, originally published in *Engineering News* of October 23d, 1913, from which it is interesting to note the practical agreement of the Consolidated and Mikado curves, and the decided departure of the E-55 curve, from that of the Consolidated engine as usually built. The curve of the Decapod—the nearest to the general 2-10-2 engine—is above the Cooper diagram for girder spans, but below it for truss spans. A study of these curves leads to the conclusion that, for the Mikado and 2-10-2 engines, with axle loads of about 60 000 lb., the Cooper loading gives satisfactory results.

* Marion, S. C.

† Received by the Secretary, July 27th, 1922.

The writer believes that the loading suggested by the author is in the right direction, but thinks its application now to the entire country is too radical, inasmuch as there is a large mileage for which the Cooper loadings will be satisfactory for a long time.

C. S. G. ROGERS,* ESQ. (by letter).†—The author of this interesting paper presents the inconsistencies of stress resulting from applying a conventional engine loading and wheel base such as that of Cooper, to the design of bridges which are to carry engines of axle loadings and wheel spacings relatively so different from the conventional loading.

The new loading, M-60, appears amply to cover all stresses in all lengths of spans that may result from the use of five of the heaviest, present-day types of engines. If all these five types of locomotives were in use on any one railroad, the proposed conventional loading would admirably conform to the requirements. Is this the case, however? Is it not rather that each railroad appears to be developing its engines along lines peculiar to itself?

The force of the author's arguments, therefore, seems to point, not to a conventional engine loading that will prove satisfactory, no matter what type of locomotive is used, but rather to loadings that will specifically meet the type of locomotive peculiar to the railway under consideration. Unless this is done, the extra material put into the bridge structure to suit the requirements of engine loadings of foreign roads is a direct and needless waste and will never be called on to function.

It is noted, too, that although the main argument centers about the new conventional loading, M-60, other loadings proportional to the front group of drivers and to the uniform train load are recommended for those railways the locomotives of which are not of the size of the five heaviest under consideration.

The fact is, however, that where the engines used are of a less powerful type, they are not merely reduced models of these heavier types (2-8-8-8-2, 2-10-10-2, 2-10-2, etc.), but usually have different groupings of drivers. The problem, therefore, does not appear to be solved by adopting a loading lighter and regularly proportional to M-60, but rather in discovering a loading which will conform to the various locomotives in use or likely to be used on the special railway under consideration. No one of the five railways, the heavy locomotives of which have been considered in developing the loading, M-60, is concerned in making its bridges strong enough to carry the heavy locomotives of the other four railways.

Looking at the matter from another angle, it is shown that the Cooper E-60 loading nearly satisfies the stress requirements for these five heavy engines for the longer spans, yet would leave an over-stress of approximately 25% in some of the shorter spans. Conversely, should the engines in use on any railroad reasonably conform to any of the Cooper loadings (a not unreasonable supposition), the use of the M-60 loading (or one of a proportionate series) would result, in the shorter spans, in a waste of the 25% excess material that the M-60 loading would provide. Therefore, from this point of view, too, the adoption of the M-60 loading is not the real cure for the evils resulting from

* Bridge Engr., Canadian National Rys., Eastern Lines, Moncton, N. B., Canada.

† Received by the Secretary, July 27th, 1922.

a loading that does not conform to the actual loading, and the problem still appears to be the discovery, on the part of each railroad, of a conventional loading to satisfy its special needs.

The author, however, has made a valuable contribution to the problem of bridge design in so forcibly calling to the attention of the bridge engineer the inconsistencies resulting from adopting an arbitrary engine-loading diagram without carefully analyzing, on a percentage basis, the relation between the stresses produced by the heavier or critical engines in actual use on the lines under his jurisdiction and those produced by the conventional engine, and correcting the latter before adoption.

E. A. STONE,* Esq. (by letter).†—The writer has read this paper with interest. The author's reasons for classifying the Cooper system of loading among the relics of the past seem to be beyond dispute, and, therefore, his proposed new loading system is a long step in the direction of filling a recognized need.

The three solutions of this problem indicated in the paper probably cover in general all methods that might be brought forward. The first method, a wheel-load diagram, would be a continuation of present practice and, after having made up a table such as that shown in Fig. 2,‡ it would be as simple to apply as any other method.

The author is entitled to the sincere thanks of all bridge engineers for the exhaustive manner in which he has presented this subject, particularly in the tables and diagrams.

Would it not be desirable and opportune, in view of the present state of bridge specification loadings, to appoint a committee to consider this matter fully and endorse the author's proposed M-60 loading, or bring forward some other loading which might be deemed preferable?

HAROLD C. BIRD,§ Assoc. M. Am. Soc. C. E. (by letter).‖—For more than thirty years the subject of concentrated wheel loads has been discussed. This paper, fortunately, comes at a time when members of the Society are interested in the adoption of a new specification for bridge design and construction.

When the late Theodore Cooper, M. Am. Soc. C. E., first specified his Class A and B as Consolidation locomotives, he probably did not anticipate that the Consolidation type of locomotive would be the type governing bridge design for so many years. Familiarity with the Cooper series should not prevent the adoption of another live load specification if the latter more nearly fits the needs. The idea of any load system specified is not to represent an actual engine or train, but to be an imaginary group of wheels (or its equivalent) which should give as great, if not greater, stresses than any which are likely to occur at present or in the immediate future. If the Cooper loading does this, and does it economically, there is no reason to make change.

* Montreal, Que., Canada.

† Received by the Secretary July 31st, 1922.

‡ *Proceedings*, Am. Soc. C. E., May 1922, p. 1053.

§ Prof. of Civ. Eng., Pennsylvania Military Coll., Chester, Pa.

‖ Received by the Secretary, August 2d, 1922.

The author has treated the subject in a thorough and enlightening manner which should convince those who will permit themselves to be convinced, that the Cooper loading does not carry out the idea expressed previously, nor does it fit the needs for rating bridges. The fact that there was difficulty in the shipping of some of the new locomotives is another indication that bridges are not prepared to carry the loads of the present time.

Although the writer has used Mr. Steinman's charts (similar to Plate XI*) in the classroom for several years and has felt that they are satisfactory, he imagines that many engineers have never used them and thinks it would be well if the author would illustrate the use of the charts with typical problems and show how they are plotted. The writer notices that the tables are not labeled with longer and shorter segments, which is an oversight.

The discussion† by F. E. Turneaure, M. Am. Soc. C. E., on the Tentative Specifications for Steel Railway Bridges submitted by the Special Committee on Specifications for Bridge Design and Construction, or the original,‡ should be referred to by all those studying this paper. The writer has calculated a number of cases using Mr. Steinman's proposed series and has been pleased to note how well the values fit the maximums of the moment and shear diagrams of the American Railway Engineering Association. The making of such diagrams and especially the calculation of shear and moment tables similar to those in Ketchum's "Structural Engineers' Handbook," would be a helpful addition to the paper.

The paper will also serve somewhat as a stop to the arguments as to whether concentrated wheel loads, equivalent uniform, or a uniform load with excess or excesses should be used, for, here, engineers can have their choice, with results practically identical. This will give those who so desire, an opportunity to visualize and, in addition, will offer those who desire excess loading, an opportunity to have their way. The formula submitted should also merit a great deal of attention.

The idea suggested by Henry B. Seaman,§ M. Am. Soc. C. E., that live loads shall consist of either the Cooper or the Steinman series, as may be specified by the engineer, is a good one.

If nothing else is accomplished by this paper, engineers have been given an easy way to compare the stresses produced by the Cooper series with those produced by the heavy engines of to-day.

ALMON H. FULLER,‖ M. AM. SOC. C .E. (by letter).¶—It is difficult to foresee the far-reaching effect of this paper. The Cooper loading no longer represents even to an approximate degree the modern locomotives and trains; it is still used, first, because it has been used; second, because tables and diagrams are available for ready computations; and, third, because nothing better has been offered.

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* *Proceedings*, Am. Soc. C. E., May, 1922, p. 1047.

† *Proceedings*, Am. Soc. C. E., December, 1921, p. 720.

‡ *Proceedings*, Am. Ry. Eng. Assoc., Vol. XXI.

§ *Proceedings*, Am. Soc. C. E., April, 1922, p. 948.

‖ Prof. of Civ. Eng., Iowa State Coll., Ames, Iowa.

¶ Received by the Secretary, August 21st, 1922.

It seems apparent that the third reason has been removed by the presentation of this paper. The second reason is also partly met by the tables and diagrams which have been presented by the author. Other tables, such as moments and shears for various panel lengths and numbers of panels for truss work and for moment, shears, and floor-beam reactions for girder spans, may be constructed, the work on which would be insignificant in comparison with its importance. The first reason has validity beyond that of natural inertia. The Profession is now accustomed to refer to loads and capacities of structures in terms of the Cooper standards, and a re-adjustment is only a natural consequence of the transition period which necessarily accompanies any of the momentous changes that are a part of progress. To persist in the use of this obsolete standard would be not only unscientific, but would result in uneconomical designs.

Of the three suggestions which Mr. Steinman has offered, one may likely have difficulty in making a choice. The writer would eliminate the second suggestion; although it has the merits claimed by the author, it lacks the definite picture presented with the first and the scientific background of the third suggestion. The writer has tried to get the viewpoint which evidently leads Mr. Steinman to prefer the third, but has yet been unable to do so to the extent of giving up the concrete picture presented by the first suggestion.

It is true that the formula would prove to be a "time saver" (for certain classes of work), that its scientific foundation yields curves of greater regularity and smoothness, and that it is independent of reference books to a certain extent. In these days, little designing or stress computation is done, or need be done, without access to an office library. When the tables and diagrams of the paper have been supplemented by the tables* for moments and shears adaptable to structures with panels by O. E. Selby, Jun. Am. Soc. C. E., and by girder tables for shears, moments, and floor-beam reactions, such as are now so generally available for the Cooper loading, the work of computation will be as simple for the engine diagram as for the formula. The diagram will be much more expressive than a formula on a drawing or in a specification. The fact that the formula gives a different uniform load for various parts of the same span, makes it necessary to refer to tables or diagrams for rapid work, and the use of the table or diagram will require as much time from one as from the other. Even though general use shall be based on the engine diagram, the formula, either in memory or in notebook, will be a convenient device for computations which must sometimes be made quickly and without office facilities. The author apparently had this in mind in referring to it as a "time saver." The writer wishes in no way to depreciate the ingenuity of Mr. Steinman in establishing this formula. He recognizes it as an asset in putting a finish on the entire discussion and in having a legitimate practical application as previously noted. He believes, however, that the greatest contribution from a practical standpoint lies in the first suggestion for a definite engine diagram.

After another half century or so, this diagram may represent existing loads no better than that of Cooper does at present. If that should be the case, the

* *Transactions*, Am. Soc. C. E., Vol. XLII (1899), p. 223.

Profession, perhaps, will find it worth while to make another re-adjustment, and in doing so, this paper should prove to be of great assistance. If the author can show that the formula may be readily extended to rapidly changing situations, it would not only be an added reason for adopting the third suggestion, but, perhaps, the controlling one as well.

CARLTON T. BISHOP,* ESQ. (by letter).†—The author has shown that the Cooper loading has outgrown its usefulness. It has served its purpose well, but the modern loadings have not increased proportionately, and some change should be made. A much simpler form of loading could be devised to give results as satisfactory as those which the Cooper loading now gives, but this would not be sufficient. Any new loading should give approximately the same results as the actual loads which are likely to be used in the near or distant future.

The author has made an exhaustive study of existing loads and of the trend toward the future. He has devised a composite loading which appears to be satisfactory, but, best of all, he has developed a formula for equivalent loads, which has great possibilities. This formula, or its corresponding tables or diagrams, can be used more advantageously than the concentrated loads and gives consistently good, if not better, results. No one system of concentrated loads can give precise stresses for different actual loads, and the simpler equivalent uniform load seems much superior. Mr. Steinman has blazed the way by proposing a formula for uniform loads in terms of segments of the span, thus overcoming the principal objections to the use of equivalent loads, that have heretofore been advanced. The stresses obtained from these new equivalent loads provide for any of the critical engines of to-day, and, probably, by proportion, those for years to come.

The writer hopes that future specifications will give the live load in terms of such a formula as that suggested by the author. Before such adoption, however, a committee should study the question and agree that the proposed formula is the best obtainable.

CLYDE W. MACCORNACK,‡ M. AM. SOC. C. E. (by letter).§—The writer is much interested in this excellent paper which is one of the most valuable contributions to bridge engineering literature in the past twenty years. It has been generally recognized for some time that the Cooper loadings do not properly represent modern locomotive loadings. Pressure of daily work has no doubt prevented many engineers from making as careful an examination of this subject as they have wished, and they will welcome the data contained in the paper, which give facilities for making the necessary comparisons. It is to be hoped that, as a result of this paper, a more modern system of locomotive loading will be generally adopted.

A standard type of loading should represent within close limits the actual loads in use. The proposed wheel-load diagram appears to satisfy this condition. Methods of computing stresses by means of the engine diagram have

* Asst. Prof., Structural Eng., Sheffield Scientific School, Yale Univ., New Haven, Conn.

† Received by the Secretary, August 22d, 1922.

‡ Chf. Engr., The Phœnix Bridge Co., Phœnixville, Pa

§ Received by the Secretary, August 29th, 1922.

been so fully developed that the labor involved is not an important consideration. The engine diagram, representing actual loads in service, should always be used in examining existing structures. It does not follow, however, that the engine diagram should necessarily be adopted for designing new bridges. Any system of loading which will give resulting stresses equivalent to those of locomotives in use, would appear to the writer to fully satisfy the requirements. If economical designs can be produced by a simpler loading, it should be substituted for the engine diagram.

It is of advantage to adopt a loading which would have the general characteristics of the actual loads on the structure. Bridge floors and short-span bridges without floors are subjected to direct loads from the locomotive drivers. In the writer's opinion, such parts and structures should be designed for the heaviest actual loads in service. The stresses in trusses and girder parts where the loads are applied through a floor system, reach the trusses and girders in the form of panel concentrations. This form of loading is as well represented by a uniform load as by a system of wheel loads. The writer believes that a system of wheel concentrations representing the heaviest loads in use should be adopted for bridge floors and for short spans without floors and that a uniform load should be used in designing all other bridge members. The computation of stresses for such a system of loading would be reduced to the simplest operations, and, at the same time, the visualization of the loadings would be retained in the designer's mind. A load formula such as that offered in the paper or, if preferred, modified to coincide more nearly with the composite loading, should give as satisfactory results as an engine diagram.

It is to be hoped that this paper will result in the adoption of a new standard system of loading representing modern locomotive loads. The important consideration is not the type of loading, whether it be an engine diagram or an equivalent uniform load formula, or any modification of these, but that the new loading be such that it will represent correctly conditions created by modern locomotives in all parts of the bridge structure.

C. P. Disney,* Esq. (by letter).†—Mr. Steinman is to be congratulated on having made such an exhaustive study of this subject. His proposals are practical and may be considered as a solution of the need for a system of calculating stresses in bridges, which is abreast of the present progressive development of locomotives and trains in the United States.

All three of the alternative proposals presented have distinctive advantages over present methods. The third proposal, however, seems to be ideal, as it is a formula which can be memorized and used, without tables or charts, to find the moments and shears at any point of a span by a simple slide-rule operation.

As regards the application of this proposed system of loading to Canadian railways, it would appear that, although Mr. Steinman's system could be modified to conform to locomotives and trains operated in Canada, the Santa Fé type is, the writer believes, about the limit, considering the capacity of

* Acting Bridge Engr., Canadian National Rys., Eastern Lines, Toronto, Ont., Canada.

† Received by the Secretary, September 5th, 1922.

roadbeds and bridges, and this locomotive, with a train of 100-ton capacity cars, can still be taken care of by using Cooper's loading.

In a 200-ft., through truss span, the maximum difference between the stresses produced by the Cooper E-55 loading and the corresponding stresses produced by a double Santa Fé, with a 5 500-lb. following load, including the floor system, is only 5 per cent. The 5 500-lb. load can be considered as a train of 100-ton capacity cars, which is the most severe probable condition of loading likely to occur on Canadian lines.

In conclusion, the writer would state that he considers Mr. Steinman's proposals to be in line with the advanced type of trains operated in the United States to-day, whereas the Cooper system conforms to the type of trains operated in Canada, which type seems likely to continue for many years.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

SOME NOTES ON THE LOCATION AND CONSTRUCTION OF LOCKS AND MOVABLE DAMS ON THE OHIO RIVER, WITH PARTICULAR REFERENCE TO OHIO RIVER DAM NO. 18

Discussion*

By Messrs. Gardner S. Williams and Morris Knowles.

Gardner S. Williams,† M. Am. Soc. C. E. (by letter).‡—Several years ago, the writer was confronted with the problem of providing, in a storage dam, a gate through which large quantities of logs could be sluiced at variations of pond level through a range of 20 ft. The width of the opening required by the lumbering interests was 30 ft. After considerable investigation, his attention was directed to the three-leaf bear-trap gate of the so-called Lang type, built in 1894, on the Chippewa River at Chippewa Falls, Wis. It had a length of 80 ft., with a rise of 6 ft., and had then been in service more than 20 years. An examination of the design of this structure, which was of timber, indicated that by the use of steel the type could be readily applied to a rise of three times that in the existing example. A similar timber structure came to notice later. It was built in 1891 on the St. Croix River at Nevers, Wis., and had a crest length of 80 ft. and a rise of 16 ft.

The so-called Island Lake Dam of the Great Northern Power Company on the Cloquet River, about 22 miles northeast of Duluth, Minn., was thereupon equipped with a bear-trap gate of the Lang type, having a rise of 20 ft. and a span of 30 ft. As far as the writer is aware, this is the highest rise under which a bear-trap gate has thus far been operated. The gate was placed in service in 1915 and has been in satisfactory use since.

The success of this gate has led to the use of this type by the writer for the discharge of flood waters in connection with power developments on the Huron

* Discussion of the paper by William M. Hall, M. Am. Soc. C. E., continued from May, 1922, *Proceedings*.

† Cons. Engr., Ann Arbor, Mich.

‡ Received by the Secretary, May 11th, 1922.

River in Michigan. At the Geddes Plant of the Detroit Edison Company, there are two such gates, each having a span of 24 ft. and a rise of 11 ft. At the Superior Plant of the same Company, the writer has installed a similar gate, the operation of which is made automatic by the use of a siphon which exhausts the water from under the gate when the pond rises above a desired level. The seal is broken when the water surface is lowered and the gate then rises to its original position.

As the operation of these gates simply requires the opening or closing of an inlet or outlet valve, they can be readily manipulated by one man, and if used in connection with a power plant, motors can be installed on the valves and the apparatus controlled from the power house at any desired distance.

A description of the Island Lake Dam has been published,* as well as a valuable Symposium on Movable Dams† which is interesting not only as to matters of design, but also as to the history of the bear-trap gate. The Sector Dams of the Sanitary District of Chicago at the Lockport Power House have also been described,‡ as well as the 160-ft. bear-trap dam§ above Lockport.

In the gates designed by the writer, it has been found desirable to use rollers under the up-stream end of the idler. Such rollers had not been generally used on the timber structures previously built, but when metal members are in contact, rollers are frequently necessary.

MORRIS KNOWLES,|| M. AM. SOC. C. E. (by letter).¶—The author's noteworthy contribution on the design and construction of movable dams on the Ohio River is of timely interest to the student of rivers and of the effects of man's regulating and restrictive works thereon. It may be worth while to note some of the discussions and opinions as to the effects of movable dams on flood heights and the care necessary to insure sufficient water for lockages during times of low flow.

The author states:

"It is well known that a project substituting fixed dams for movable dams would be less expensive; but the requirements of navigation *and the popular fear of an increase in flood heights,* made the building of fixed dams in this river appear at that time to be impracticable."

And William W. Harts, M. Am. Soc. C. E., states:**

"The Ohio is subject to extreme floods. Sometimes, as much as 70 ft. in range is recorded, and great injury and loss invariably result to the towns along the banks. Nothing could be allowed in the bed of this stream that would be likely to increase this range, *and in the public mind fixed dams were objectionable for this reason.*"††

The writer remembers the discussion and conferences that took place in 1915 when the project for the substitution of a fixed dam at Emsworth, about

* *Engineering News-Record,* August 2d, 1917.

† *Journal,* Assoc. of Eng. Societies, June, 1896.

‡ *Engineering News,* November 12th, 1908.

§ *Loc. cit.,* March 28th, 1898.

|| Cons. Engr., Pittsburgh, Pa.

¶ Received by the Secretary, June 5th, 1922.

** *Proceedings,* Am. Soc. C. E., April, 1922, p. 1007.

†† The italics in this and other quotations in this discussion are the writer's.

six miles below the Point at Pittsburgh, for the movable type of dam at Davis' Island, called Dam No. 1, was under consideration. Many were apprehensive that this new dam, about 21 ft. high above the bed of the stream, would seriously increase the flood heights at Pittsburgh. The writer was asked to review the situation for the City of Pittsburgh and the Pittsburgh Flood Commission. He was much gratified to report, after many studies and calculations, that a disastrous flood of 35.5 ft., such as occurred in 1907, would be increased at the Point by less than 1 ft. by the erection of such a fixed dam, and that an extreme flood, 10 ft. higher, which might happen by a combination of fortuitous circumstances, would be increased to a negligible degree. Thus, when this report became known, much of the opposition to the fixed type of dam at this location disappeared.

Much has been said about the tightness of wickets, gates, bear-traps, etc., and the attendant possibility that, during low-water stages, there may not be sufficient water for the large number of lockages required for full navigation potentialities. The author states:

"Considering the question of tightness, Condition 7, it is believed that bear-trap dams can be made as tight as any other type of dam. Needles, curtains, gates, and, possibly, other types can be made tighter than wickets. With the use of wickets, calculations should show a shortage of water not more than once in 10 to 20 years. * * * Computations indicate that, with pass wickets 15 ft. high, with weir wickets, 12 ft. high, and with the pass and weir of the lengths proposed, the leakage through the interstices between the wickets will about equal the discharge of the river at a 3-ft. stage. Therefore, during several weeks of each year, needles over the interstices will be necessary."

Again, on page 1005,* Earl I. Brown, M. Am. Soc. C. E., states:

"In the operation of this system of locks and dams, much trouble has been experienced by reason of inability to raise the dams at stages higher than about 9 ft. This results in the impounding and holding back of the discharge of the river in the pools of those dams that are raised, with a consequent rapid falling off in the discharge of the river at points lower down. * * * So great has this effect on the discharge of the river become, that much delay and obstruction to navigation has at times been experienced at and below Louisville, by reason of the manipulation of the dams at and above Cincinnati. As the number of dams in operation increase, the effect on the lower part of the river will become more and more marked, and, at times, *may result in an almost complete absorption of the discharge of the river* if great care is not exercised in the raising of the upper dams."

That this fear of insufficient lockage on streams made artificially navigable by locks and dams is a real menace, is shown by the following statement from the report of the Pittsburgh Flood Commission, published in 1912, after a long period of careful investigation and research:

"Under present conditions there are serious troubles with shortage of water on the Monongahela River during dry weather. * * * At such times the pools farthest upstream are drawn down to furnish water for the pools nearer Pittsburgh, and through navigation is impossible, the upper pools being sometimes lined with barges waiting for water to float them downstream. * * * The reports of the Chief of Engineers of the United States Army give the

* *Proceedings*, Am. Soc. C. E., April, 1922.

minimum discharge of the Monongahela as 160 sec-ft. which occurred in 1895, the dryest season in recent years. This is only about two-thirds of the discharge of 244 sec-ft. necessary to supply water for 180 lockages, even if there were no other losses."

It thus appears there is danger when complete navigation facilities will have been provided and if they are utilized to the utmost of traffic capacity. The report quoted previously states elsewhere that the low water of the Monongahela will be increased six times and that of the Allegheny to three times its minimum by the use of storage reservoirs. The Ohio at Wheeling, W. Va., 90 miles below the point of particular observation at the time of the study, will be raised 2.3 ft. at the time of lowest stages.

Surely an amplification of such a system is all that is needed further to improve conditions farther down stream. It is a mistake to argue that the beneficial effect of storage is negligible, except just immediately below a reservoir constructed for such a purpose. The effects on flood flows and the raising of low stages are likewise noticeable many miles away. The writer holds no brief for contemplated accomplishment of navigable depths by letting out stored waters as a general and universal proposition, but to say that such have no use in augmentation and helpfulness is an unnecessary attempt at a reversal of the laws of hydraulics.

Mr. Thomas P. Roberts* has stated,

"*It has been proved that to reduce materially the height of great floods at Pittsburgh, restraining reservoirs should be as near as possible to the city,* for the flood-producing storms reaching Western Pennsylvania are only rarely more than 90 miles in width of excessive precipitation. * * * Had the 1913 storm moved eastward only 80 miles farther, careful study indicates that, at Pittsburgh, the flood would have been at least 15 ft. higher than the record flood of 1907. It is useless to attempt to estimate the damages which would have resulted from such a flood to the towns, bridges, etc., above Pittsburgh. * * * *To talk of restraining reservoirs for such floods, at least for the area above Pittsburgh,* is waste of time."

The carefully prepared studies in the report of the Pittsburgh Flood Commission, previously referred to, which was approved by a Board of United States Army Engineers as to practicability and feasibility, in 1913, states the highest known flood at Pittsburgh, that of 1907, would have been reduced 10 ft., or to a stage of 25.3, only 3.0 ft. above danger, by the construction and proper manipulation of seventeen selected reservoirs out of a total of forty-three possible sites. Other floods, which had occurred over a period of 50 years, would have been reduced below the danger line. Surely this controverts such an extravagant statement of the over-zealous objector. It is a good principle of life to secure the good we can, even if one's 100% desire cannot be obtained.

In this connection, it is interesting to note the remarks by Col. Brown:†

"To meet this difficulty, a comprehensive scheme of control of operating the dams will have to be devised, so that constant reports as to the stages of the river and variations of discharge may be received at a central point, at which will then be determined the proper time for the raising and lowering of all dams, and thus regulate them so as to affect the discharge in the lower

* *Proceedings*, Am. Soc. C. E., March, 1922, pp. 732–733.

† *Proceedings*, Am. Soc. C. E., April, 1922, pp. 1005–1006.

parts as little as possible. A telephone system is being provided, connecting all dams to a central point, which will probably be Cincinnati, and that will be the point from which this centralized control will be exercised. After some means can be devised whereby the dams can be raised at stages above 9 ft., much benefit will be gained, and it is understood that attempts are now being made to devise some method of raising the dams at higher stages."

This is just the sort of managerial control that is exercised in inter-related gravity water supply systems and is exactly what the Pittsburgh Flood Commission planned for the comprehensive system of reservoirs proposed by it.

The author's remarks regarding the Government's activity in water transportation evidently caught the atention of L. M. Adams, M. Am. Soc. C. E., who pertinently asks the question in conclusion:

"What would the situation be if the waterways had been improved at the expense of private capital, which always demands interest and return of the original investment? This problem looms large to the rail carriers and their security holders."

Again, as Col. Harts* so aptly states:

"The supreme test of the public value of any inland waterway must always be an economic one. * * * How many of the inland streams, on which extensive navigation projects have been built, can now meet this test?"

It is hoped to have soon a legislative determination, based on an enlightened public opinion, that munificent expenditures for improvements to navigation are only warranted—if judged alone, without other effects as to the economic advantages to transportation to be obtained thereby—when all the fixed charges and overheads, as well as operating and maintenance expenses, to be borne either directly or indirectly by the traffic, are less than for some other means of transportation and distribution of products. When this enlightened day comes, perhaps there will be less opposition to the acknowledgment of the thesis that a stream should be considered as a whole from its source to its mouth. Thereby, many potential uses will be studied and amplified and some of the costs of the work will be distributed over many objects, and the burden to any one will be proportionately lessened.

* *Proceedings,* Am. Soc. C. E., April, 1922, p. 1008.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

TENTATIVE PLAN FOR THE CONSTRUCTION OF A 780-FOOT ROCK-FILL DAM, ON THE COLORADO RIVER, AT LEE FERRY, ARIZONA

Discussion*

By Samuel Fortier, M. Am. Soc. C. E.

Samuel Fortier,† M. Am. Soc. C. E. (by letter).‡—The people of the West are much interested in feasible plans to utilize the waters of the Colorado River. Even a partial utilization of this river might affect for good or ill the citizens of seven Western States. Perhaps the most valuable part of the author's paper on this subject is in outlining the wonderful potentialities of this river, when properly controlled, in furnishing water for irrigation, producing energy, and protecting fertile lands from floods. He might have added a fourth, namely, the settlement and retention of the river sediment within the natural channel of the river.

For several years, the U. S. Bureau of Public Roads, under the direction of C. E. Tait, M. Am. Soc. C. E., has been carrying on an investigation of the silt problem of the Colorado River, in co-operation with the State of California and the irrigation interests of the Imperial Valley of California. As a part of this investigation, daily samples were taken at Hanlon Station, the river intake of the Imperial Canal System, from July 1st, 1917, to June 30th, 1918, to determine the percentages of silt entering the System from the river. These percentages were ascertained by filtering out and weighing the solids contained in the muddy water of each sample.

In Table 4 is given the maximum, minimum, and average daily percentages by weight for each month of the period covered.

Owing to the uncertainty in ascertaining when silt has reached its least volume in the process of consolidation, it is more difficult to express with

* Discussion of the paper by E. C. La Rue, M. Am. Soc. C. E., continued from September, 1922, *Proceedings*.

† Associate Chf., Div. of Agricultural Eng., Bureau of Public Roads, U. S. Dept. of Agriculture, Berkeley, Calif.

‡ Received by the Secretary, August 21st, 1922.

the same degree of accuracy the percentage of silt by volume. From October, 1907 to September, 1908, samples of equal volume were taken daily from the turbulent water below the gates at a number of stations of the Imperial Canal System and poured into one container for each calendar month. The composite samples thus obtained were then shaken and settled for 30 days in glass tubes, 1 m. high, after which the percentage of silt was noted. The results obtained on the Main Canal at Hanlon Head-gate was a maximum of 3.8% in August, a minimum of 0.9% in July, and a mean for the year of 1.6 per cent. If due allowance is made for differences in the quantity of silt carried in 1907-08 and 1917-18, a percentage of 1.6 by volume would compare in a general way with a percentage of 0.242 by weight.

TABLE 4.

Date.	Maximum percentage by weight.	Minimum percentage by weight.	Average percentage by weight.
July, 1917	0.750	0.063	0.232
August, 1917	1.033	0.174	0.574
September, 1917	0.516	0.074	0.145
October, 1917	0.990	0.129	0.371
November, 1917	0.249	0.060	0.111
December, 1917	0.159	0.064	0.080
January, 1918	0.217	0.050	0.088
February, 1918	0.219	0.036	0.083
March, 1918	1.309	0.121	0.609
April, 1918	0.540	0.103	0.286
May, 1918	0.322	0.140	0.266
June, 1918	0.269	0.019	0.061
Mean			0.242

In 1919, there was delivered to the Imperial Irrigation District 1 584 312 acre-ft. of water diverted from the Colorado River, and this quantity of water was applied to 413 440 acres of land. These figures do not include the quantity of water delivered to lands in the Republic of Mexico, served by the same system. In that year, the cost to the Irrigation District and to the several subsidiary companies known as mutual water companies for removing silt from the canals, amounted to approximately $1 000 000. This cost did not include that incurred by the farmers in removing silt from farm laterals, damages to crops as a result of silt, or modifications necessary on account of yearly accumulations of silt on cropped fields. This extra cost incurred by the farmers may be conservatively estimated at $2.00 per acre per annum, thus bringing the total damages caused by silt in one year to $4.42 per acre irrigated.

If it is true, as reported, that 1 220 000 acres are irrigable from the lower part of the Colorado River, the damage inflicted by silt in one form or another, unless much better controlled than at present, would impose yearly a heavy financial burden on the part of the water users.

It is evident, therefore, from what has been stated, that the waters of the Colorado River should be stored not only to provide water for irrigation, develop power, and prevent floods, but also to retain the river silt. The cost of such storage on a large scale by concrete dams is not likely to exceed $2.25

per acre-ft. The quantity of water required to irrigate such crops as are grown on the Lower Colorado Basin is usually less than 3 acre-ft. per acre, measured at farmers' deliveries. Accordingly, the first cost of storing enough water to irrigate 1 acre of land in this basin, exclusive of transmission losses, would be about \$6.75, as compared with \$4.42, the present annual cost of removing silt from channels and compensating land-owners for the injurious effects of depositions of silt on irrigated land.

It will be noted by a reference to Table 4, that the average percentage of silt by weight is 0.242. The waters of the Colorado River at Yuma, Ariz., contain slightly more than double this quantity, or 0.5 per cent. The difference is due to skimming and other processes by which the water admitted to the main canal of the Imperial System is rendered more free of solid matter.

As to the author's tentative plan to store water at Lee Ferry, the writer regrets that he cannot approve of the site selected or the plan proposed. The site is too far removed from available irrigable lands, settled communities, or transportation facilities. Owing to the long distances between the dam site and the markets for power, only a small percentage of the hydro-electric energy which might be developed could be utilized. Besides, as the writer has tried to point out, the retention of silt is an important factor in storing water, and by locating the reservoir at Lee Ferry the tributaries which carry the largest quantity of silt would enter the main river below the reservoir.

As regards the author's tentative design for a rock-fill dam in the channel of the Colorado River at Lee Ferry, the feasibility of blasting enormous quantities of rock at a low unit cost into the channel from the adjacent side-walls in the manner proposed will not be questioned. To render water-tight such a quantity of blasted rock so placed, in the writer's opinion, would be impractical in any such manner as that proposed. The author states that the loose rock in the dam would be about 15% greater than the space occupied by the same material in its natural compact state. This is evidently an error, as authorities are agreed that when 1 cu. yd. of solid stone is broken into pieces, it will occupy when loose about 1.9 cu. yd. In other words, the voids in broken rock generally run from 40 to 50 per cent. In blasting rock in the manner proposed, a fairly large percentage would be thrown into the river gorge in large, irregularly shaped masses, some of which might contain 1 500 cu. yd. When piled up on the site of the dam, these large masses would contain correspondingly large open spaces. There is a further possibility that these large open spaces would be connected, thus permitting large quantities of water to pass through, especially if the water was under high pressure. The author proposes to render such a mass of loose rock water-tight, first by sluicing in broken rock varying in size from 1 to 6 in., followed by the sluicing of sand. The bulk of such rock could not well enter the larger cavities, except through the transporting power of the water. So little could be done to control the action of the water in moving the smaller rock particles from cavity to cavity that the element of chance assumes large proportions. In fact, the whole procedure would be a game of chance. Perhaps the rock particles might find a lodging place, and then, again, perhaps

they might be borne through the structure by the force of high heads of water. In any event, the greatest efficiency that could be expected would be that a relatively small part of the voids in the rock-fill could be filled in this way. The author also proposes to sluice sand into the open spaces when the latter are filled with broken rock. The use of sand, however, is based on the belief that the cavities would first be filled with the smaller broken rock. Otherwise, the sand would be transported through the rock-fill.

A Combination Concrete and Rock-Fill Gravity Dam.—Although the writer believes that it would be unsafe as well as unwise to build a loose rock-fill dam in the manner outlined, and that if a dam is built in Boulder Canyon, or elsewhere on the Colorado River, it will be of concrete throughout, he is of the opinion that a certain percentage of loose rock, having the open spaces well filled with finer material, might well form part of a concrete gravity dam of the dimensions under consideration. The foundation of a combination structure of this type, up to the natural high-water elevation, would be laid in concrete in the manner customary in building gravity dams, but the superstructure would consist of massive concrete walls enclosing compartments filled with broken rock, gravel, sand, and rock dust. By exercising care in grading and in placing the rock materials, the specific gravity of the loose rock in place could be made to approach 80% of that of the concrete, whereas the cost per unit of volume of rock-fill in place, as compared with concrete in place, would be about as 1:3.

This suggestion is merely a new adaptation of an old idea. From the days of the Pilgrim Fathers, the pioneers of every State in the Union have made use of wooden crib-dams filled with rock. Unless the native logs or sawn timbers, of which the cribs are built, are continuously submerged, early decay is inevitable. In these days of higher cost of timber, as compared with that of concrete, this old type of pioneer dam might well receive renewed attention, providing concrete, either plain or reinforced, can be used in lieu of timber. For example, some advantages in the way of lessened cost might be derived in using this combination structure for relatively low diversion dams by building on a secure foundation a skeleton structure of reinforced concrete, enclosing compartments to be filled with loose rock. At the other extreme, as regards the height and other dimensions of dams, is to be found such a structure as is contemplated for one of the canyons of the Colorado River. Nothing approaching any such structure in size has ever been built, and the internal stresses produced by the setting of the concrete and changes in temperature would be more or less conjectural; whereas in building what might be termed a skeleton dam of concrete, but of ample strength, the thickness of the several longitudinal ribs would be well within established practice. The general form of such a type of dam would not differ materially from the common gravity type, except that the dimensions would have to be increased to take care of the lesser specific gravity of the loose-rock portion as compared with concrete. The up-stream face would also consist of a series of sharp arches abutting against the vertical longitudinal ribs and against the side-walls of the canyon. These ribs, in turn, would be tied into arched cross-ribs, thus enclosing compartments of the

general form of the frustrum of an inverted pyramid. Such a form would tend to wedge in and compress the loose rock placed therein. A drain to bed-rock could be installed in the base of each compartment, and provision made to drain each compartment. There would be no horizontal partitions in any compartment, but the top of each might be sealed with reinforced concrete if found to be desirable.

The main advantage in using loose rock in conjunction with concrete, in a dam of the kind proposed, lies in the lessened cost. If such a structure could be designed to consist of 40% loose rock, the saving in first cost would be considerable. Other minor advantages might lie in greater elasticity and better facilities for expansion and contraction joints and draining the foundation. The reduced shearing strength along horizontal planes and the difficulty in designing safe multiple arches on the up-stream face, however, might prove disadvantageous.

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PAPERS AND DISCUSSIONS

TENTATIVE SPECIFICATIONS FOR STEEL RAILWAY BRIDGES

Submitted as a Progress Report of the Special Committee on Specifications for Bridge Design and Construction

Discussion*

By Messrs. Charles Evan Fowler and Alfred S. Niles, Jr.

Charles Evan Fowler,† M. Am. Soc. C. E.—The speaker was asked to come from Detroit, Mich., presumably to apologize for what had been said in his written discussion.‡ It is his wish to say, however, that he has some very decided opinions about bridge specifications, and, as many have asked, "Who started this fight?", it is well to plead guilty, because at the time investigations were under way on the Niagara Railway Arch Bridge, the speaker had frequent occasion to go to Montreal, Que., and Ottawa, Ont., Canada, and to meet many members of the Engineering Institute of Canada. The Committee of the Institute was at work at that time on a new set of specifications, as was the Committee of the American Railway Engineering Association; and it seemed desirable, with the talk there had been of the Society preparing a new railway bridge specification, that all ought to combine and write a joint specification. Therefore, George H. Pegram, Past-President, Am. Soc. C. E., and J. E. Greiner, M. Am. Soc. C. E., were asked to join the speaker in a letter to the Board of Direction, with such end in view. This letter was written in March, 1919, asking that a committee be appointed to co-operate with the American Railway Engineering Association and the Engineering Institute of Canada in writing such a joint specification. This committee was appointed, but for some reason did not function properly, and

* Continued from August, 1922, *Proceedings*.

† Cons. Engr., New York City.

‡ *Proceedings*, Am. Soc. C. E., April, 1922, p. 904.

the matter was dropped. Later, when Henry B. Seaman, M. Am. Soc. C. E., came with a second letter to the Board of Direction, asking it to appoint a committee to write a new specification for the Society, the speaker signed that letter, still believing that something might result better than the A. R. E. A. specification, which did not seem to be the last word as to what a modern specification should be.

That any committee is going to be able to write a specification that all will like or all agree on, does not seem probable, either now or at any future period; so it may be stated, fully and frankly, that Cooper's specification, gotten up as it was, and used over a long term of years, was probably the best solution of the specification idea. It was prepared by an individual, not to cover his own idiosyncracies, but to cover the best things of current practice. It has never been excelled in any way, and that was what the speaker had in mind when he stated in his discussion, previously referred to, that, although this Committee was one of great individual ability, any one member could, almost over night, write a better specification than the one submitted. As one of the greatest world philosophers said, "First of all, let's get the facts".

It does not matter what specification the A. R. E. A. may publish, or what specification the Society may write, each railway or each large system will likely continue to have its own specification. They will usually modify the specification standardized by a technical society to suit their own needs. The A. R. E. A. proceeded with its specification, regardless of the fact that the Society did not join in it; and the speaker wrote to O. E. Selby, Jun. Am. Soc. C. E., Chairman of the A. R. E. A. Committee, about a number of things that had come up in his practice, particularly at Niagara, especially as to column formulas, unit stresses, impact, and locomotive loadings. An invitation was received to attend the Committee meeting at Pittsburgh, Pa., which meeting was held, the speaker thinks, in October, 1919. The question of a column formula was discussed by Professor Turneaure and about sixteen other Committee members, all of whom agreed that the logical thing to do was to take all the tests on columns, of the past thirty years, and weed out the columns that were poorly designed, poorly tested, or had failed in detail. This would leave the data of good columns, properly tested, from which to plot curves for the different end conditions, and then decide logically what column formulas to adopt, which would be likely to conform with the ideas of some of the discussors, with Mr. Seaman, and particularly with Mr. Pegram's belief that, when such results are obtained, they will agree closely with the Gordon formula. The A. R. E. A. Committee did not carry out this work.

O. E. Hovey, M. Am. Soc. C. E., worked out the lines or formulas for the light and heavy sections from the report of the Special Committee on Steel Columns and Struts; and from the diagram (Fig. 15) that appears in the Niagara paper,* it can be seen that the Gordon formula, as there plotted, and the lines as plotted by Mr. Hovey, are nearly parallel for the central part of the Gordon curve, or from $\frac{40\,l}{r}$ upward; so that some Gordon formula, in the

* *Transactions,* Am. Soc. C. E., Vol. LXXXIII (1919-20), p. 1959.

speaker's opinion, will finally satisfy every one, and one need not worry about the working out of a complicated formula, because, as Mr. Seaman has shown, it can be tabulated once for all.

The other major matters taken up at the Pittsburgh meeting were unit stresses and locomotive loading. The question of unit stresses for alloy steels is referred to subsequently, but such unit stresses should certainly not be less than two-thirds of the elastic limit of any material used, or on the basis of 20 000 lb. in tension for structural steel.

It may be interesting to give some idea of the investigations being made for the Detroit long-span bridge, which must be largely of alloy steel. Neither in the Society's nor in other general specifications is anything said about structural steel other than the ordinary 55 000 to 65 000-lb. steel. Nickel steel and silicon steel are being used very often, and certainly a comprehensive specification ought to cover them and the corresponding unit stresses. At Detroit, the only silicon steel offered was one with an elastic limit of 45 000 lb., and a steel with an elastic limit of 55 000 lb. is required. This was taken up with one of the best metallurgists in the United States, and the speaker is certain that the officials of the bridge companies, if shown the letter from him, would say he was a high authority. The chemical analysis that he recommended for silicon steel to give an elastic limit of 55 000 lb.—and it is highly important generally that such a steel be made—was carbon, 0.60; manganese, 1.00; phosphorus, 0.04; sulphur, 0.05; and silicon, 0.45. This steel would have to be drilled; the Detroit material, however, is all of a thickness that would require drilling. The analysis of silicon steel with the usual elastic limit of 45 000 lb., with an ultimate strength of from 80 000 to 90 000 lb. per sq. in., is carbon, 0.40; manganese, 1.00; phosphorus, 0.04; sulphur, 0.05; and silicon, 0.45. In his book on "Alloy Steels," Hibbard gives a silicon steel with carbon, 0.48; manganese, 0.45; phosphorus, 0.04; sulphur, 0.05; and silicon, 1.40, which, on testing, gave an elastic limit of 71 100 lb., and an ultimate strength of 113 760 lb. per sq. in. It is very desirable that tests should be made on the series of silico-manganese-molybdenum steels, referred to by Mr. G. W. Sargent before the American Society for Testing Materials, with carbon from 0.10 to 0.55; manganese from 0.45 to 0.75; phosphorus less than 0.04; sulphur less than 0.05, silicon from 1.75 to 2.00; and molybdenum from 0.25 to 0.50. Alloy steels of proper strength must be arranged, if no other way seems possible, by committees of the various Societies going to the high officials of the steel companies and asking them to change the rules that do not allow the mills to deviate from the standard steels that they are now making at their basic and electric open-hearth furnaces. At present, one has to take what they make or go without. Some of the mill officials state that they cannot turn out a higher silicon steel than the usual grade now made as standard, but they must learn that engineers have investigated and know the cost of the elements. That ferro-silicon is very much cheaper per ton than ferro-manganese is well known, yet the mill officials do not hesitate to vary the percentage of carbon or manganese any way they desire, without charging anything extra, and sand or quartz is very much cheaper than manganese.

One other thing that might be said about using alloy steels, is that the shop and mill officials seem to think they are going to be cut out of much tonnage, but if they make a steel with an elastic limit of 55 000 lb., or nearly double that of structural steel, there will not only be twice as many bridges built as at present, but most probably three or four times as many. The shops and mills can go back to their war-time tonnage if they will meet the buyer's views. They are selling to the man who is going to use the bridge, and the engineer is only an intermediary. They will most surely get a much larger business by co-operating with the buyer.

The specification for cable wire for Detroit is very close to the Manhattan Bridge specification, and to what had been worked out to some extent for Philadelphia, with carbon, 0.85; manganese, 0.60; silicon, 0.24; sulphur, 0.04; phosphorus, 0.04; and copper, 0.04. The wire mills immediately wanted that changed. One firm wanted it changed one way, and another in another way. Finally, the sulphur was changed to 0.055, and the copper to 0.20; and an American company then said it could give an ultimate strength of 230 000 lb. per sq. in. and an elastic limit of 65% as desired, but when the bids were received an English firm was the only one that gave a real price on the specification, and stated it was the only firm in the world that could furnish steel of that quality. It is not necessary to blush for American manufacturers, because that is not so; but it is a commentary on what engineers are up against, that they cannot get steels in the United States that can be readily had abroad. Of course, at Detroit, there was the peculiar condition of an International bridge, where the wire could be readily brought from England. This is one thing that the Committee ought to do, give the facts as to the ultimate that can be used in alloy steels.

In the matter of locomotive loading, the A. R. E. A. Committee insisted on adhering to Cooper. The Committee had prepared a number of diagrams (two of which are published in the speaker's closure of the Niagara paper*) purporting to show that the Cooper loading was close enough; E-60, however, was as much as 15% too light for the shorter spans and probably 5% too heavy for the longer spans, as compared with actual loadings. The diagrams did prove just what has been brought out in this discussion, and what D. B. Steinman, M. Am. Soc. C. E., has worked out for his M-loading.† In the fore part of the Niagara paper, the same idea was proposed that Mr. Steinman has worked out in detail; that is, a composite moment curve of the heaviest existing locomotives. It does not matter whether what Mr. Steinman has worked out, or what was worked out at Niagara, is taken, one will have a comprehensive curve that will cover all loadings. P. B. Motley, M. Am. Soc. C. E., Engineer of Bridges of the Canadian Pacific Railway, has also used such a scheme, and other railroads have adopted similar methods, possibly ante-dating even the speaker's idea.

Mr. Steinman has stated in his paper that, at Niagara, an E-60 loading was used for the long span and E-70 for the remainder of the bridge, leaving

* *Transactions*, Am. Soc. C. E., Vol. LXXXIII (1919–20), pp. 2021 and 2023.

† "Locomotive Loadings for Railway Bridges," *Proceedings*, Am. Soc. C. E., May, 1922, p. 1043.

one to infer that such was the best we knew or could do. This was not true, and it will be noticed by reference to that paper this same idea of a composite loading was there evolved, but in a different manner. Standard locomotives were developed with no idea of using them as actual loadings, but as future standards to which the motive power departments and locomotive builders should adhere, more especially as to the wheel spacings and relative loads on driver axles and other axles, and to be used in calculating the composite curve. Referring to Fig. 30, Class A would be the standard for Mallet type locomotives, A-50, having 50 000 lb. on each driver axle, A-60, having 60 000 lb. on each driver axle, and A-70, having 70 000 lb. on each driver axle, or an exactly similar nomenclature as the old Cooper loadings. Class B would be the standard for the Santa Fé type of locomotives. On Fig. 31, Class C would be standard for the Mikado type, and Class D for electric locomotives.

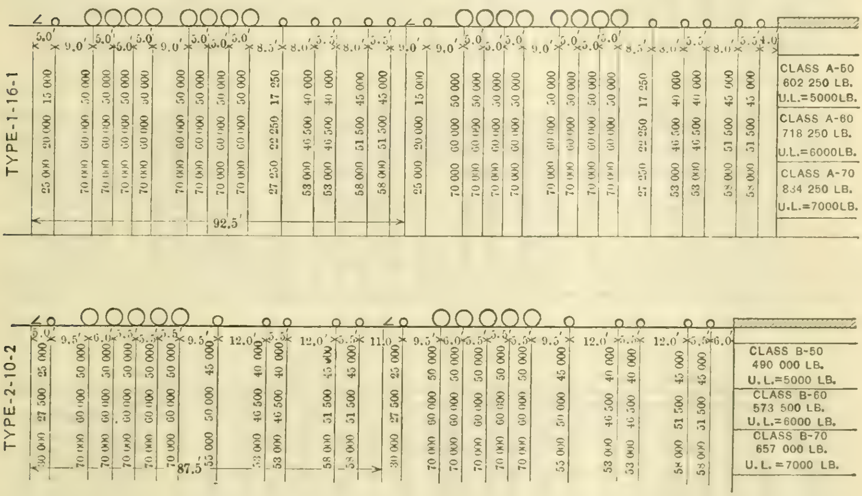

FIG. 30.

Is it not worth an attempt on the part of the Committee to obtain conferences and endeavor to reach such an agreement? The idea is that when such a system of loading, like that of the speaker as used by Mr. Steinman, is developed, it would then be lasting; thus it would seem that this Committee, the A. R. E. A. Committee, and, perhaps, others, should go to the locomotive builders, the motive power departments, and ascertain if something cannot be agreed on as future standards for wheel spacing and axle loadings of locomotives. The railroads found out during the World War that it was necessary to have more nearly one standard, and the speaker believes the bridge engineers of the trunk lines, and these various Committees, would find that the railroads would now welcome the co-operation of the Engineering Societies with themselves and the locomotive builders to standardize still further, so that in a monumental line of work, such as preparing new loading tables, the work would last, instead of being out of date in possibly a decade.

The A. R. E. A. Committee stated that it was afraid to drop the Cooper loading, largely because the railroad managers and operating officials could not understand anything but Cooper. That does not properly state the case, as the real idea is that they have all their tables made up, and their bridges standardized, by the Cooper loading. Mr. Seaman has shown that it is easy to set opposite one of the composite loadings, the equivalent one of the Cooper loadings, for any length of span, so that the Cooper loading can be used as a measuring stick until gradually it is forgotten.

Referring to the matter of impact formula, it was found at Niagara that some loadings gave more than 100% on short spans. Many variations in impact were found on the 550-ft. span, as compared to other data, owing to the fact that impact is due, not only to the sudden application of the load, but also to unbalanced drivers, bad rail-joints, vibration, and all the additions that a strain-gauge, or whatever instrument is used for taking impact readings, will sum up in a total which will cover everything that is deleterious to the structure.

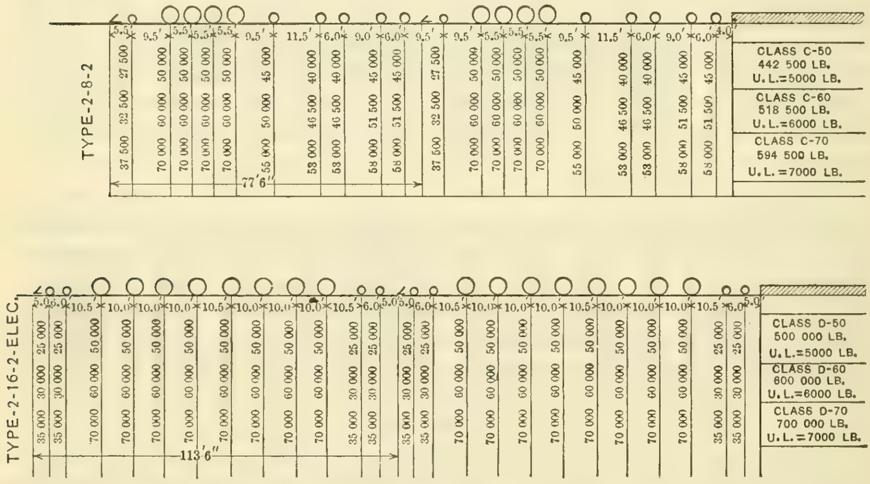

FIG. 31.

The speaker believes that the English formula presented is the best for a simple curve that could be developed. C. W. Lloyd-Jones, Chief Engineer, H. E. H., The Nizam's Guaranteed State Railways, India, who came to the United States in 1921, spent some time with Professor Turneaure, and obtained a great many impact data. He stated before returning that already a formula was partly completed, and would be developed fully, that would take care of the critical speed, variable speed, panel length, loaded length, relative dead and live load, and all items that would enter into the problem, so that the final result would be a complete impact formula. The first report from this source, which was received some time ago, stated that the full report covering the final conclusions would be sent later. When it comes, the speaker

believes that the Committee will find some valuable data worked out in far-off India, some of which are based on American observations which have not been applied nor heeded.

However, what is needed most, granting that the A. R. E. A. specification is sufficient for drafting-room and shop rules, is a specification for the greater problems of design and ultimate facts, and if such a one can be produced, it will be of world-wide value. Probably, little fault can be found with the majority of the clauses in the A. R. E. A. specification, but the speaker has no doubt that the discussion in this Society will cause the A. R. E. A. Committee to modify very many points. The best thing to do, however, if the Committee of the Society is determined to get out a detail specification, is to hold it open until the next revision of the A. R. E. A. specification, possibly in 1923, and ask the Engineering Institute of Canada to join in an endeavor to accomplish what was hoped for in 1919 and died for lack of proper nursing —a joint specification.

Although the bridge engineers of the trunk lines state that their high officials cannot understand the changes in locomotive loadings, yet A. H. Smith, President of the New York Central Railroad, has just had built by the Lima Locomotive Works—called on the Michigan Central, No. 8 000—a wonderful machine, in which there has been used each individual thing about a locomotive that has been found up to date and best, and all combined in one locomotive, which the speaker understands is going to be wonderful in the saving of fuel and in hauling trains up to 100 or 125 cars—if the draw-bar heads will stand it. A recent number of *Railway Age* also contains notes of a new Swedish locomotive, which is driven by a condensing steam turbine. This is an entirely new departure in locomotives. It has been running for some time, and shows a saving, it is said, of about 52% of fuel. However, there is a further point to notice in regard to this Swedish locomotive; the turbine is geared to driving wheels on the tender. Of course, such a locomotive will do away with all unbalancing and hammering, and would probably agree very closely with the proposed composite typical locomotive, having the heavier or driving wheels at the rear. Therefore, if railroad presidents are taking such interest in these details there may soon be seen locomotives of the Swedish type, practically turning the locomotive end for end, and giving us an altogether different type of loading. What the speaker is getting at by citing these two cases, is that the high railroad officials do understand details, and are looking for the best. The best points possible should thus be used for a specification, and set down as the ultimate things; and the speaker believes the time has come when such work can be completed, so that a specification will result that can be worked up to, instead of worked down to, as is now the case.

In writing a specification, one should not begin by including all the little details, because the officials of good fabricating companies know how to punch holes, and to do reaming and drilling, and with the proper inspection they can go ahead and do good work; and the good inspector should only expect to have good work. These and all details are of such long standing that they should be in separate books of rules, such as the Navy Department uses for

each different class of work and material, or by having a set of rules for the drafting-room and another set of rules for the shop, thus leaving the specification a real one of basic principles only, and basic things of design, or the facts that all must work up to.

One may ask what is meant by basic facts? In a recent three-page paper presented by the speaker at Toronto University, to be published in its last engineering monthly, on the subject of "Artistic Design of Bridges", a few principles are given, that are the ones an engineer should observe if it is desired to have a bridge look right; and there certainly is no use in designing a structure, unless it is made to look half way artistic. These fundamental facts are Simplicity, Harmony, Symmetry or Balance, and Proportion. In that short paper, these principles are defined somewhat at length. Further, a specification should treat more fully as to the types of bridges for different locations and classes of loads. For example, engineers often do not understand why, at Detroit, the speaker planned a suspension bridge with a span of 1 815 ft., to carry railroad trains. They say, "this type was a failure at Niagara, why go back to it?" Some do not realize that the inertia in the longer span allowed the use of a suspension bridge in such a case, where it could not be used for a short light span. Then why not state also the ultimate facts about cantilevers, suspension, and long-span bridges? Why stop at 300 ft., or at data for building an ordinary girder or truss bridge? The same thing will apply, of course, to a number of matters in a specification. One should not merely give unit stresses for short spans, or impact for short spans, or other short-span data; the data should apply equally to all different lengths and types of bridges.

The speaker does not know—perhaps, it can be learned—how far the co-operation of the fabricating companies can be had in working out many of these things. Some time ago, he wrote a paper on "Evolution in Bridge Design",* and he thinks the members of the Committee would find it of value to take a copy of that paper, correct the many typographical errors, and use it to refresh their minds on what has happened in the last forty or fifty years in bridge design. There have been a lot of things done, a lot of things tried out, that need not be gone over again. The speaker does not know whether many engineers realize that, in beginning the use of steel in the Nineties, larger unit stresses were used than at present. There has been a retrogression. The Southern Railway, the Baltimore and Ohio Railroad, and other railways, have used a unit stress of 17 000 lb. in tension for some time.

Bridge engineering may logically be divided into six periods; the first period is the Historical, previous to 1800; the second period, that of Primitive Trusses, from 1800 to 1840. From those days came the Towne Lattice and some other simple trusses. The third period was that of Modern Trusses, from 1840 to 1860. From this period came the Howe and Whipple trusses and the Pratt truss. The fourth period was that of Long Truss Spans, from 1860 to 1880, and one of the first long spans, at Cincinnati, Ohio, has just been replaced—the old Cincinnati Southern Bridge, designed by Bouscaren and built by Linville. The fifth period the speaker has called the period of

* Published in the *Journal* of the Western Society of Engineers, December, 1920.

Scientific Design, from 1880 to 1900, covering the work done by Messrs. Johnson, Cooper, Thacher, and all the old-timers at bridge design. The sixth period was the period of Commercialism, from 1900 to 1920. The speaker thinks all engineers must realize that progress in bridge engineering stopped about 1900. It has not gone ahead very much; all that was desired was bridges and tonnage; and it is to be hoped that in this present, or Ultimate Period of twenty years, from 1920 to 1940, it will be possible to get away from the past and get down to the Ultimate Facts, as has been stated before, and to what is really wanted for use in bridge design as the Ultimate.

The matter of punching and reaming, or else drilling, is a feature that ought to be made more definite. Of course, it is realized that officials of shops now equipped for punching and reaming do not wish to throw away their machinery; but some of them are gradually turning their equipment into drilling machinery, and have been stating for some time that their shops can now do drilling just as cheaply or more cheaply than they can do punching, so the speaker does not see any reason, if that is so, why the reaming clauses cannot ultimately be dropped from specifications and save that great economic loss or extra cost in bridgework.

TABLE 10.—LIMITS FOR FOUNDATION METHODS.

No.	Type.	Minimum depth, in feet.	Economic maximum depth, in feet.	Maximum possible depth, in feet.
1	Earth bank coffer-dam	1	6 to 7	8 to 10
2	Log crib coffer-dam	4	14 to 16	20 to 25
3	Sheet-pile coffer-dam	5	14 to 16	25 to 30
4	Removable box coffer-dam	5	10 to 12	15 to 20
5	Cribs and tubes	5	18 to 20	20 to 30
6	Open dredged caisson	20	80 to 90	250
7	Diving bell caisson	10	40 to 60	80
8	Pneumatic caisson	20	70 to 80	110
9	Combined diving and pneumatic caisson	20	90 to 100	110+
10	Ballmatic caisson	60	80 to 90	250
11	Freezing process	25	40 to 80	125
12	Grouting process	10	30 to 60	125

A few words might be said about what Mr. Seaman has written about foundations in his Tentative Specification.* Here, again, it is certainly not desirable to go into too much detail; but it would be desirable to cover some things that never have been covered. Some time ago the speaker gave to *Engineering and Contracting*,† some data (Table 10), that had been worked out on foundation types, that is, what type of foundation is applicable to certain conditions and certain depths. Twelve types were given from earthen bank coffer-dams, through various types of coffer-dams, to dredged cribs and caissons, showing the minimum and maximum possible depth for each class of foundation. There will be found a great many young engineers wholly at sea when they try to decide the type of foundation to use for their structure, yet they know perfectly well where to look for the engineering formula to determine how many and what length of piles are required.

* *Proceedings*, Am. Soc. C. E., April, 1922, p. 946.

† March 16th and 23d, 1921.

There is another class of data which ought to be covered, that is, "unusual engineering forces". The speaker has had occasion to go into the question of hurricanes, hurricane waves, hurricane storm tides, and ice pressures; and, lately, on a bridge being built in California, of going into the matter of earthquakes and geological forces. These are all things that one might say are so special that it is not necessary to cover them in a specification; but if it is desired to write a real specification, instead of merely reference rules for the drafting-room or shop, these things—the latest, best, and ultimate things—should be covered.* It is surprising the work one has to do, often spending months on one of these special problems gathering data to get a report in shape, so that the client can be told the ultimate facts to which one is willing to subscribe.

The new specifications, therefore, should cover only points of general design and general detail, while the sections covering Unit Stresses and Details of Design should be printed in a separate pamphlet for use in the designing, drafting, and templet departments of the railway and bridge companies. Likewise, the sections covering the Quality of Materials and Workmanship should be printed in a separate pamphlet for the use of railway purchasing and inspection departments and the shops of the bridge companies; and a third pamphlet on Inspection, Painting, and Erection. These sets of rules can then be referred to by number in the general specification.

This general specification then should cover General Designs; Artistic Features; General Data; Loads and Unusual Forces; Unit Stresses; Details of Construction; and Material and Workmanship, in two separate pamphlets; Inspection, Painting, and Erection in detail, or else in a third pamphlet; and Foundations in general, with foundation details, preferably in a separate pamphlet.

Each large railway, or at least each great system, will undoubtedly, as stated, have its own general specification, but there need be no reason for duplicating the matter suggested for printing in the three separate pamphlets.

But let us repeat, "First of all, let's get the facts".

Alfred S. Niles, Jr.,† Jun. Am. Soc. C. E. (by letter).‡—The writer has been much interested in the discussion of the column formulas proposed by the Committee. In designing airplane structures, it is necessary to use very slender columns and low factors of safety. On account of these two characteristics of airplane structural members, much research work has been done on columns of both wood and steel, the results of which are not well known to the Profession. Although the columns used in airplanes are small, they cover a wide range of slenderness ratios, and give interesting information on the subject of columns in general.

The most important result obtained is that the Euler formula will give the failing load for a truly centrally loaded column, provided the Euler load is less than the failing stress of the material in direct compression. Some of the most interesting tests have been made on spruce columns, which, owing

* *Engineering and Contracting*, June 28th, 1922.

† Aeronautical Structural Engr., Research Dept., McCook Field, Dayton, Ohio.

‡ Received by the Secretary, September 1st, 1922.

to the lack of homogeneity of wood, one might expect inconsistent results. The average crushing strength of airplane spruce is about 6 000 lb. per sq. in. and the average modulus of elasticity about 1 800 000 lb. per sq. in. The ultimate stress by the Euler formula equals the crushing strength at values of $\frac{L}{r}$ between 50 and 60 for pin-ended columns. A series of tests was recently made at McCook Field, under the writer's direction, in which all struts with slenderness ratios of 60 or over failed at values slightly below the ultimate according to the Euler formula. Struts with slenderness ratios of 50 and 40 failed at practically the same load as short pieces cut from the ends of the same specimens. Great care was taken to prevent eccentricities of loading, and if any measurable deflection was obtained under about two-thirds of the expected ultimate, the column was reset in the testing machine. This procedure eliminated nearly all eccentricities, whether due to lack of homogeneity of material or any other cause. The difference between the actual failing load and the Euler load was evidently due to the small eccentricity remaining.

These McCook Field column tests were made under laboratory conditions which could never be approached in engineering practice. Their value lies in proving that the lower limit of the range in which the Euler formula applies is much smaller than had previously been believed, and that the reason for using other formulas for short struts was not because the Euler formula did not hold for such struts, but because the effect of eccentricities becomes so great in the short columns that the Euler formula is no longer a safe approximation. The Euler formula does hold if the conditions are those for which it was developed.

The real problem in column design is that of making a reasonable allowance for the effect of the eccentricities which are, partly at least, unknown in magnitude. When the Euler formula gives unit stresses less than one-half the yield point of the material, the effect of the eccentricities usually encountered is so small that it may safely be neglected as taken care of in the factor of safety. This puts the lower limit of the practical range of the Euler formula at about $\frac{L}{r} = 120$ for structural steel. As bridges have few, if any, structural members with such high slenderness ratios, the Euler formula is of little use to the bridge designer.

For columns with slenderness ratios in the range of bridge practice, allowance must be made for the effect of eccentricities, and it is most profitable to view the proposed column formulas in this light. As the eccentricity and degree of restraint of the ends of the actual column are impossible to determine accurately, it is necessary to apply empirical constants in any practical formula for columns in this range. All the formulas that are proposed for short columns have these empirical constants, even though they also have a more or less theoretical basis. This applies to the Rankine formula, and the many "eccentricity" and "secant" formulas proposed.

The column formula which should be used for practical design is the one which combines in the greatest degree, ease of application, and agreement with

test results. These advantages belong to the parabolic and straight-line formulas. The studies of A. Ostenfeld, in 1898, on the better known experimental work, by the method of least squares, indicated that these formulas give the smaller and the Rankine and eccentricity formulas the greater mean errors.* As these formulas are not only the most easily applied, but also represent the test results the most accurately, the writer can see no reason for the attempt to use complex formulas like those proposed by Mr. Chew† and Mr. Hunley.‡ These formulas have a more theoretical basis than the parabolic formulas and appear to be more accurate, because they allow for the initial eccentricity. This appearance of accuracy, however, is illusory, as the initial eccentricity must be assumed or found empirically, and as Ostenfeld has showed, the results are not in as close agreement with the tests as those of the simpler and frankly empirical formulas.

In airplane design the parabolic formula is exclusively used for short columns, with excellent results, for both wood and steel members. It is easy to apply, and the constants have a definite connection with the properties of the material.

* Salmon, "Columns", p. 231.

† *Proceedings,* Am. Soc. C. E., August, 1922, p. 1467.

‡ *Proceedings,* Am. Soc. C. E., April, 1922, p. 915.

MEMOIRS OF DECEASED MEMBERS

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

CYRUS GILDERSLEEVE FORCE, JR., M. Am. Soc. C. E.*

DIED FEBRUARY 7TH, 1922

The death of Cyrus Gildersleeve Force, Jr., has removed another of those civil engineers whose activities left their impress on the Science of Engineering during a period when the development of municipal engineering work was in its infancy. The ranks of these pioneers, made up of a sturdy group of men, many of whom were without special educational training and all of whom working with little precedent to guide them really accomplished wonders, have been thinned by retirement or death until, to-day, only a few are to be found in active practice. It is impossible to estimate the importance of the work done by these men and its value to later engineers, but that it was of great importance is always realized, when, as death takes one of their number, one stops to consider and dwell on his accomplishments.

Cyrus Gildersleeve Force, Jr., who was a worthy member of this group of pioneer engineers, was born at Ledgewood, N. J., on August 27th, 1841. He began his engineering career at about the end of the Civil War, having previously obtained his general education at the Chestnut Hill Academy at Succasunna, N. J., and at the State Normal School at Trenton, N. J., from each of which institutions he was graduated.

During several years, he taught school in New Jersey and Indiana, meanwhile preparing himself for the work which, later, became his profession. He early directed his studies into the field of bridge design and construction and obtained employment with Zenas King, of Cleveland, Ohio, a pioneer in iron bridge construction and the founder of the King Bridge Company.

Mr. Force served as Chief Engineer for two years with this Company, during which time, many bridges in various parts of the United States were designed and completed under his supervision.

Prior to 1870, he entered the Engineering Department of the City of Cleveland, where he remained, in various capacities, for many years. The records show that he was City Engineer from 1884 to 1887, and, again, from 1890 to 1893, and, later, he returned to the Department as Assistant Chief Engineer from 1895 to 1899. Since 1899, he had devoted his time to consulting engineering practice in New Jersey, making his home at Ledgewood, where he died on February 7th, 1922.

In August, 1892, Mr. Force was married to Miss Cora May Williams, of Cleveland, who, with a sister, survives him.

Mr. Force was greatly interested in bridge construction and during a part of his employment with the City of Cleveland, he specialized as a Bridge Engineer, and, later, as City Engineer, he retained a keen interest in bridge

* Memoir prepared by Robert Hoffmann, M. Am. Soc. C. E.

work. He served as a member of the Committee appointed to inspect the piers of the Brooklyn Suspension Bridge while it was being constructed.

During Mr. Force's time, the office of City Engineer was subject to change in personnel, depending on the political complexion of the Common Council. This explains the lapses in the continuity of his connections with the City Engineer's Office, and this condition of interrupted service makes it difficult to state definitely the exact work which may have been started by him or that which he continued or carried through to completion. Many projects started under his supervision were finished later under other supervision, and, likewise, work begun by others was carried on or completed by him. Under his direction, many miles of sewers and pavements were built in Cleveland. Mr. Force was an ardent advocate of the building of large sewers and substantial pavements. The large Walworth Sewer was one to which he gave much attention, both as to its design and construction. Several large bridges, one of which was the Central Viaduct, were under construction during his incumbencies of the City Engineer's Office, and received the benefit of his direction. Many other adaptions of engineering work which come under the direction of a city engineer, were efficiently considered and conducted by him, with the energy and the natural engineering ability for which he was noted.

The years which have elapsed since Mr. Force's engineering career in the City of Cleveland ceased, have proven his great worth and have shown him as a man whose life efforts must be conceded to have been of benefit to mankind.

Mr. Force was elected a Member of the American Society of Civil Engineers on February 6th, 1878, and always took a keen interest in the welfare and work of the Society.

REGINALD GILLON CHRISTOPHERS, Assoc. M. Am. Soc. C. E.*

Died October 13th, 1918.

Reginald Gillon Christophers was born in Dunedin, New Zealand, on August 8th, 1882, and was the eldest of a family of five sons.

He began his schooling in Dunedin, but his father who was a Bank Manager, was transferred to Invercargill when his eldest son was 9 years old. At Invercargill, the boy went through the Public School course of New Zealand, and afterward spent three years, 1897-99, at the Southland Boys' High School, from which he matriculated. While at school, he was diligent and thorough in his duties and, at the same time, took a leading part in the school sports, excelling at Rugby football.

It was while he was a student at the High School that Mr. Christophers began his military training, rising to the rank of Sergeant in the High School Cadet Corps. On leaving school, he joined the Volunteers and again succeeded in earning a Sergeant's Certificate at an unusually early age. This

* Memoir prepared by Denniston Cuthbertson, Esq., Invercargill, New Zealand.

training, no doubt, stood him in good stead when he went into camp to prepare himself for the part he was to play in the World War.

On leaving school, Mr. Christophers took up agricultural pursuits, but after a short time, he decided to become a Civil Engineer and Surveyor. To this end, he served from July, 1901, to December, 1904, as Survey Cadet under Messrs. John Spence and T. S. Miller, respectively, Civil Engineers of Invercargill, passing with credit his examination as a Surveyor in 1904 and topping the New Zealand list for that year. In January, 1905, he accepted a position with the New Zealand Government as Assistant Surveyor, in charge of a field party on road and settlement surveys. He relinquished this position in June, 1906, and came to the United States, where he remained until 1911. During this period his record reads, as follows:

From August, 1906, to February, 1907, Transitman with the Atchison, Topeka, and Santa Fé Railway Company, on maintenance of way, at Oakland, Calif.; March to September, 1907, in charge of a location party on the Monterey, Fresno, and Eastern Railway, at Monterey, Calif.; October, 1907, to January, 1908, Engineer on Construction for the Ransome Concrete Company, at San Juan, Calif., on heavy foundation work, in charge of all earthwork, reinforcement, etc., and also assisted the Superintendent; June to September, 1908, Transitman for the U. S. Deputy Surveyor, on summit of Sierra Nevada Mountains, California; September, 1908, to December, 1909, Transitman and Instrumentman on location and construction of the Western Pacific Railway, serving for two months as Resident Engineer on 20 miles of construction; January to April, 1910, made a contour survey of a large dam site for the Sierra and San Francisco Power Company, Angels Camp, Calif.; April to November, 1910, Assistant Engineer with the Western Pacific Railway Company in charge of a party on filing map surveys in Feather River Canyon, California; December, 1910, to March, 1911, with the Union Lumber Company, Fort Bragg, Calif., making an estimate of the cost of building railways; March to August, 1911, Assistant Office Engineer to J. B. Pope, M. Am. Soc. C. E., who was in charge of revaluation for the Southern Pacific Company, making revaluation profiles and estimating the cost of bridges and culverts on the entire system of the Oregon Railway and Navigation Company; and August to December, 1911, District (Locating) Engineer for the Coos Bay and Eastern Railway in Oregon, making a preliminary survey for 45 miles of proposed railway.

Returning to New Zealand in 1911, Mr. Christophers began the private practice of his profession as a member of the firm of Robinson and Christophers, at Stratford, Taranaki, the firm acting as Consulting Engineers to Stratford Borough and other public bodies, as County Engineers, Whangamomona County, etc.

In 1915, Mr. Christophers was appointed Engineer to the Hobson County Council, and filled this position with distinction until 1917, when in order to join the New Zealand troops in the World War, he entered camp as a Second Lieutenant and was attached to the Machine Gunners. He soon gained the reputation of being a capable and thorough officer, keen about his work and loved and respected by his fellow officers and by the men under him, to whose welfare he never tired of devoting himself. Lieut. Christophers was a strict

disciplinarian, not only with his men, but also with himself, but his absolute fairness and impartiality soon gained for him the confidence of the troops and made his task a happy one.

He sailed from New Zealand, in June, 1918, and after a short period of training in England, joined the First Battalion, Otago Infantry Regiment, in France, from which time, he took part in some heavy fighting. He met his death in a particularly gallant manner: Leading his men in a charge against the enemy's trenches, he was held up by barb wire, and as he was cutting his way through, he was shot in the throat by a German officer. He lingered for a few days and died in the Fourth Casualty Clearing Station, France, on October 13th, 1918.

Lieut. Christophers lived his short life with a fullness given to few to enjoy. He was one who, holding the highest ideals, lived up to them nobly, setting an example which any one might do well to emulate, and finally giving his life in the finest way possible, in defense of his King and country.

While in the United States, Lieut. Christophers was married to Miss Alice Mildred Vyner, who traveled from New Zealand to join him. He is survived by his wife and two sons. His father and mother also survive him, but of their family of five sons, only one remains, the other four having given their lives to their country in the World War.

> "They shall grow not old as we who are left grow old.
> Age shall not weary them nor the years condemn.
> At the going down of the sun and in the morning
> We will remember them."

LOUIS WILLIAM KLINGNER, Assoc. M. Am. Soc. C. E.*

Died April 2d, 1922

Louis William Klingner, the son of Dr. Louis M. Klingner, was born at Toronto, Ont., Canada, on June 10th, 1886. He received his engineering education at the University of Toronto from which he was graduated in 1907. This was followed by post-graduate work at Columbia University, New York City, during 1909-10.

From June to October, 1905, Mr. Klingner served as Chainman and Rodman with the Canadian Pacific Railway Company, and from May to October, 1906, he was employed as Draftsman in the office of Division Engineer F. S. Darling, M. Am. Soc. C. E., in Toronto.

Mr. Klingner was Field Draftsman and Instrumentman on the Georgian Bay and Seaboard Branch of the Canadian Pacific Railway from May, 1907, to January, 1909. While in this position, he prepared plans for the layout of docks and quays, and the harbor at Port McNichol, on the western terminal of the line. He was also engaged on the layout of the yards and the first unit of grain elevators.

* Memoir compiled from information supplied by Fraser S. Keith, Secretary, Eng. Inst. of Canada, and on file at the Headquarters of the Society.

From January to May, 1909, he was employed on the preparation of plans for the Toronto-Sudbury Branch, and the Georgian Bay and Seaboard Railway, of the Canadian Pacific System, in the offices of the Division Engineer.

From July to November, 1909, Mr. Klingner was with G. A. Just and Company, in Long Island City, N. Y., as Detailer on structural steel, and from November, 1909, to July, 1910, he was employed by the New York Central Railroad Company as Designer on masonry and reinforced concrete for the Grand Central Terminal, New York City.

From July, 1910, to February, 1911, he was with the Foundation Company, Limited, of Montreal, Que., Canada, in the following capacities: Superintendent of Construction on reinforced concrete oil tanks, built for the Queen City Oil Company at Toronto, from July to December, 1910, and as Assistant Superintendent on the Dominion Express Building foundations in Montreal, from December, 1910, to February, 1911.

From February, 1911, to March, 1912, Mr. Klingner served as Resident Engineer on double track from Smith's Falls, west, to Glen Tay, Ont., in charge of all grading, bridges, culverts, etc., for the Canadian Pacific Railway, and from March to May, 1912, he was in charge of a party revising location on the Campbellford, Lake Ontario, and Western Railway, a branch of the Canadian Pacific Railway. In May, 1912, he was appointed Resident Engineer on Section No. 3 of the same road, in charge of all grading, laying out of bridges and culverts, and preparing plans for bridges, trestles, etc., which position he retained until August, 1913.

During the latter part of 1913 and in 1914, Mr. Klingner was employed as Company Engineer with the Dominion Construction Company, at Toronto. At the outbreak of the World War, he enlisted as a Lieutenant with the 2d Field Company, Canadian Engineers, and was engaged at first in instructing and training infantry in field works and military engineering at Toronto.

From April to December, 1915, he was in charge of construction work at Niagara Camp, and from December, 1915, to March, 1916, he was with O. C. Depot Company at the Engineers' Training Depot, at Ottawa, Ont. From March to July, 1916, he served with the 8th and 10th Field Companies, Canadian Engineers, in England, and from August, 1916, to May, 1918, he was Lieutenant in the 10th Field Company, Canadian Engineers, in France. From May to August, 1918, he served as Captain of the 10th Battalion, Canadian Engineers, and from August, 1918, to July, 1919, as Staff Captain, 4th Brigade, Canadian Engineers.

Captain Klingner was awarded the Military Cross on November 16th, 1916, for exceptional courage in bringing in, under enemy fire, a wounded Canadian officer at the Somme, risking his life for a comparative stranger. He was demobilized on July 6th, 1919.

On his return to Canada, he accepted the position of Company Engineer and Comptroller of the International Corporation of Canada, at Montreal, and, in 1920, he was appointed District Irrigation Officer in charge of all irrigation surveys in Mesopotamia, with the Irrigation Directorate, Bagdad, Mesopotamia, having under his control eighty-four local officers, with parties in the field.

On April 2d, 1922, while making a trip along the Tigris River from Bagdad to his Serrai headquarters, his motor launch was swept against a bridge pier with such force that it was crushed and sunk within 20 sec. and Capt. Klingner was drowned.

He was a man of generous nature, sterling character, and high ideals, and his loss is irreparable.

Captain Klingner was elected a Junior of the American Society of Civil Engineers on October 31st, 1911, and an Associate Member on June 24th, 1914. He was also a Member of the Engineering Institute of Canada.

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"BOND STRENGTH OF WOOD PILES IN CONCRETE." By R. R. Lundahl.

"THE COMPARISON OF CONCRETE GROINED ARCHES AS AN AID IN THEIR DESIGN." By Philip O. Macqueen.

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OF THE

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OF

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AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PROCEEDINGS

This Society is not responsible for any statement made or opinion expressed in its publications.

SOCIETY AFFAIRS

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ITEMS OF INTEREST

The Committee on Technical Activities and Publications will be glad to receive communications of general interest to the Society, and will consider them for publication in *Proceedings* in "Items of Interest". This is intended to cover letters or suggestions from our membership concerning matters which are not of a technical character. Such communications, however, must not be controversial or commercial.

Lumber Standardization Conferences at Madison, Wis., and Chicago, Ill.

In accordance with the following resolution adopted at the General Standardization Conference, held under the auspices of the Department of Commerce, in Washington, D. C., during May, 1922,

"That the grading of all lumber be divided into three great subdivisions, namely:

"A.—Representing the best qualities.
"B.—Representing the intermediate qualities.
"C.—Representing the common qualities.

"Realizing the great field for thought in developing an equality and simplification of grades in all woods and appreciating the possibility of such accomplishment, we recommend that the National Lumber Manufacturers Association set up a competent committee with efficient engineering source seeking in so far as possible to equalize grades in all woods, and that said committee confer with representatives of the consuming public, the Departments of Commerce and Agriculture, and other agencies of the Government in their efforts as the occasion demands",

the National Lumber Manufacturers Association invited representatives of lumber manufacturers and others to meet at Madison, Wis., July 19th and 20th, 1922, to prepare and suggest a basis for the equalization and simplification of lumber grades.

Those in attendance came as individuals and not in any way representing any specific organization, nor is their action binding on any organization. The attendance was, as follows: Dudley F. Holtman, Assoc. M. Am. Soc. C. E., *Chairman,* Construction Engineer, National Lumber Manufacturers Association; C. J. Hogue, M. Am. Soc. C. E., Manager, West Coast Forest Products Bureau; J. E. Jones, Chief Inspector, Southern Pine Association; T. F. Laist, Chicago Representative, National Lumber Manufacturers Association; J. M. Pritchard, Secretary, Manager, and Chief Inspector, Hardwood Manufacturers Institute, C. H. Sherrill, President, Hardwood Manufacturers Institute; George E. Strehan, Assoc. M. Am. Soc. C. E., Consulting Engineer, Southern Pine Association; Fred W. Alexander, Secretary-Manager, Pacific Lumber Inspection Bureau; and William E. Hawley, M. Am. Soc. C. E., Assistant Engineer, Duluth, Missabe, and Northern Railway Company, Committee No. 7, American Railway Engineering Association.

Members of the Forest Products Laboratory, Forest Service, U. S. Department of Agriculture, also participated in these meetings and presented for discussion and consideration, recommendations for the grading of soft wood, yard lumber, and structural timbers, as developed from its study of this matter covering a period of years. The thought of the Laboratory was to present a basis for grading, adaptable to all soft wood species, and to be varied for various products, the idea being that through uniform grade names and definitions, a grade for any purpose in any species would be of as nearly equivalent value for its particular use as the grade of the same name in any other species.

A report, based on the rules proposed by the Laboratory, was prepared, which report was submitted to a Conference held at Chicago, Ill., July 20th-22d, 1922. At this Conference, in addition to the report of the Madison Conference, other phases of the lumber industry were discussed.

A Central Committee was appointed to prepare the information preliminary to holding the final conferences. The reports of the Madison and Chicago Conferences have been placed on file in the Reading Room of the Society, where they will be available to those interested.

Engineering Societies Library Service

The Engineering Societies Library performs an important service to the members of the Society in endeavoring not only to collect and make readily

available the useful engineering publications, but also to supply information to distant members.

In filling the requests received by mail, of which fifteen to twenty arrive each day, several experienced workers are kept busy. Most of these calls are for copies of articles in periodicals, and, if the references have been given definitely and correctly, the request is soon prepared by photo-printing. The demands for information that can be supplied by this method range from 600 to 700 photo-prints per week. Probably no invention of recent years has been of more value to investigators than the photo-print method of copying.

Translations form another important activity of the Library. The greater number asked for are from the French and German, but there are calls for translations from almost every language. The task of securing the necessary combination of linguistic and technical competence is sometimes difficult, but the Library has always succeeded in securing a translation from any language desired.

Requests are also received for various kinds of information, such as the best books on certain subjects, or a list of all writings on a certain subject, formulas, constants, specifications, etc. Some of this information can be answered, quickly from experience or by reference to the catalogue, whereas other inquiries require careful research. In case the information sought will require extended investigation, a charge is made to cover the cost of such work; there is also a charge for copying and translating. In this class of work, research is continued until the desired data are collected or the limit of cost set by the inquirer is reached.

Requests are received that are outside the province of the Library. It cannot, for example, recommend engineers for employment, nor give opinions on engineering subjects or points that are in dispute. In fact, it has no opinions, except with respect to the merits of books. All it can do when confronted with a question is to search for the written statements that deal with that question. If nothing has been written on the subject, the Library is forced to disappoint the inquirer. The officials of the Library wish to stress this point as it is the most frequent cause of dissatisfaction. Many problems arise in practice that have not been solved in books, and these, unfortunately are more than the Library can handle. Within its limits, however, the Library is constantly being helpful to many members, and suggestions of new means for extending its service are welcomed.

ACTIVITIES OF LOCAL SECTIONS*

Meetings of Duluth Section

A regular meeting of the Duluth Section was called to order at 12:15 P. M., on August 21st, 1922; President W. H. Hoyt in the chair; Walter G. Zimmermann, Secretary; and present, also 24 members and 3 guests.

After the guests had been introduced, the minutes of the meeting of July 17th, 1922, were read and approved.

The Secretary presented a letter from Secretary Dunlap stating that there had been put aside for the Section forty-four volumes of *Transactions* of the Society, which is as complete a set as is now available.

The Secretary also presented another letter from Secretary Dunlap relative to his proposed trip through the West and his intention of visiting the Section on October 16th, 1922. On motion, duly seconded, the Secretary was instructed to advise Mr. Dunlap that the members of the Section would be very glad to have him on that date which is the day of the regular October meeting, and would also invite him to be present at the meeting of the Duluth Engineers' Club in the evening.

Mr. Franklin Hutchinson, Chairman of the Library Committee, supplemented his report as presented at the meeting of July 17th, 1922, by stating that he had seen the City Librarian and that the Public Library would take care of the volumes of *Transactions,* subject to withdrawal by the members of the Section. He stated further that as the funds of the Library were low, the authorities were in no position to bind the books. After discussion of the matter, it was decided, on motion, duly seconded, to ask Secretary Dunlap to ship the books, but that the binding of them would be postponed for the present. Mr. Hutchinson also stated that the City Librarian would be glad of any assistance in selecting technical and engineering books for the Library and that if any of the members will make out lists of desirable books, he would be glad to submit such lists to the Librarian.

Mr. W. H. Woodbury called attention to the proposed visit to Duluth, the Iron Range, and the Twin Cities, of Dean Cooley and Secretary Wallace of the Federated American Engineering Societies, and on motion, duly seconded, Mr. Woodbury was appointed a committee of one to make arrangements for the proposed visit.

A paper by W. B. Patton, entitled, "Meteorological Conditions at Duluth During the Past Fifty Years," was presented by the author. In discussing the paper, Mr. J. R. Stack called attention to the recent forest fires and stated that in his opinion a survey and program for flooding the fire districts should be taken up and something constructive done in the matter. He also suggested that as this was primarily an engineer's problem the Governor might be asked to appoint an engineer on the Fire Commission. It was further suggested that Mr. Patton's paper should be circulated in connection with the problem of forest fire prevention and reforestation.

After further discussion, it was, on motion, duly seconded, decided to appoint a committee of three to get in touch with the Commission now being

* For list of Local Sections, Officers, etc., see 1922 Year Book, p. 41, and also p. 626.

appointed by the Governor and report at the next meeting. Messrs. Patton, Stack, and Shepard were subsequently appointed to act on this Committee.

Meeting of September 18th, 1922

A regular meeting of the Duluth Section was held on September 18th, 1922; Second Vice-President O. H. Dickerson in the chair; Walter G. Zimmermann, Secretary; and present, also, 21 members and 2 guests.

The minutes of the meeting of August 21st, 1922, were read and approved.

The Secretary presented correspondence from Secretary Dunlap in further reference to his visit to the Section; a copy of President Hoyt's letter to Mr. L. W. Wallace, Executive Secretary of the Federated American Engineering Societies, in reference to Dean Cooley's proposed visit to Duluth; and President Hoyt's letter to the Committee appointed by the Section to advise and co-operate with the Governor of Minnesota in regard to the forest fire situation.

The Entertainment Committee had arranged for an automobile trip to visit the new bridges on the Congdon Boulevard, but owing to bad weather the trip was postponed. In lieu thereof, the Committee provided the following entertainment:

One of Kipling's "Departmental Ditties" entitled "Municipal" was read by Mr. J. R. Stack. An instructive talk was given by Mr. Noyes on the subject, "Development of Rock Drilling Machines", which was followed by an interesting discussion, at the conclusion of which Mr. Noyes was given a vote of thanks by those present. Mr. Stack followed with a short talk on "Demolition of the Fortress of Helgoland", as described recently by the Army officer in charge of this work.

Meeting of Kansas Section

A meeting of the Kansas Section was held on September 23d, 1922, following a banquet at Pelletier's Tea Room, Topeka, Kans., in honor of Secretary John H. Dunlap of the Society; President L. E. Conrad in the chair; F. W. Epps, Secretary; and present, also, 20 members and guests.

A very interesting address was made by Mr. Dunlap, in the course of which he explained the relation between the Parent Society and the Section, and outlined some of the things which the Section could accomplish both for the Society and for the local community.

A paper by Mr. P. H. Everhard entitled, "Engineering Developments in Western Kansas", was presented by the author.

An address on "The Relation of the Local Sections to the Federated American Engineering Societies", was made by Mr. Lloyd B. Smith, after which the meeting was thrown open for general discussion in which many of those present joined.

Meeting of the Nashville Section

A meeting of the Nashville Section was held on September 25th, 1922; President B. H. Klyce in the chair; L. C. Anderson, Secretary; and present, also, 6 members.

President Klyce addressed the meeting on "Some of the Unique Features of the Construction on the Miami, Fla., Viaduct."

Special Meeting of Northeastern Section

A special luncheon meeting was held at the call of the Chairman, on September 9th, 1922, at 1:15 P. M., at the Boston City Club; Chairman Frank B. Sanborn in the chair; Charles W. Banks, Secretary; and present, also, about 40 members and guests.

The guests of the Section included the members of the Executive Board of the Federated American Engineering Societies.

The social program which followed the luncheon consisted of several interesting addresses by the officers and members of the Executive Board. The speakers included Dean Mortimer E. Cooley, President of the Council; Vice-Presidents J. Parke Channing, W. E. Rolfe, and Dexter S. Kimball; Secretary L. W. Wallace, who called the roll of the Council, introducing each member in turn; C. F. Scott, President of the Society for the Promotion of Engineering Education, Mr. Philip N. Moore, and others.

Meeting of Philadelphia Section

A regular meeting of the Philadelphia Section was held at the Engineers' Club, on October 2d, 1922; President William Easby, Jr., in the chair; Charles H. Stevens, Secretary; and present, also, about 100 members and guests.

The meeting was preceded by an informal dinner at the Club in honor of the speaker, Dr. Delos F. Wilcox, of New York City, and other guests.

After the regular business of the meeting had been disposed of, the subject of the evening, "Capital Profit in Street Railway Investments", was presented by Dr. Wilcox, who discussed the "present-day tendency to increase the capital base for the purpose of rate-making, greatly in excess of the money invested, and pointed out the several ways in which this increase is made." Dr. Wilcox also raised the question as to whether "the financing of street railway enterprises should be on a speculative or non-speculative basis."

Discussion on the subject was participated in by Messrs. William S. Twining, Director of the Department of City Transit; Dean William Draper Lewis, of the Law School of the University of Pennsylvania; Sheldon Potter, representative of the Board of Directors of the Philadelphia Rapid Transit Company; and C. Oscar Beasly.

Minutes of Meetings of Spokane Section

A regular meeting of the Spokane Section was held on July 14th, 1922, at the East Banquet Annex, Davenport's; Vice-President B. J. Garnett in the chair; Charles E. Davis, Secretary; and present, also, 5 members.

On motion, duly seconded, it was decided that the Section go on record as being in favor of the applications of Messrs. A. A. Young and F. G. Harvey for membership in the Society.

On motion, duly seconded, it was decided to suggest the name of Mr. J. C. Ralston as the Section member of the Sub-Committees on Power and on Harbors and Waterways.

Meeting of August 11th, 1922

A regular meeting of the Section was called to order on August 11th, 1922, at the East Banquet Annex, Davenport's; Vice-President B. J. Garnett in the chair; Charles E. Davis, Secretary; and present, also, 12 members.

As there was no business to be taken up, the meeting was devoted to a general discussion of the problems of the day.

Meeting of September 8th, 1922

A regular meeting of the Section was held on September 8th, 1922, at the East Banquet Annex, Davenport's; President C. A. Burnette in the chair; Charles E. Davis, Secretary; and present, also, 11 members.

The proposed visit of Secretary John H. Dunlap of the Society was discussed, and President Burnette appointed a committee, consisting of Messrs. Butler, Tiffany, and Richardson, to arrange for Mr. Dunlap's entertainment.

On motion, duly seconded, it was unanimously decided by those present that Mr. J. D. Koren be recommended for membership in the Society.

Meeting of Utah Section

A special meeting of the Utah Section was held on September 28th, 1922, at the Weber Club, Ogden, Utah; Vice-President E. A. Porter in the chair; H. S. Kleinschmidt, Secretary; and present, also, 12 members and 2 guests.

Following a dinner which was given in honor of Secretary John H. Dunlap of the Society, at which he and Mr. H. T. Plumb, President of the Utah Engineering Council, were guests, Mr. Dunlap addressed the meeting with particular reference to the newer activities of the Parent Society in an endeavor to bring the membership closer together.

Following Mr. Dunlap's address, Vice-President Porter called on each member present to make a few remarks, in order to enlighten Mr. Dunlap as to the past history, present conditions, and future possibilities of Utah, with particular reference to the Engineering Profession.

Luncheon in Honor of Secretary Dunlap

On September 28th, 1922, a luncheon in honor of Secretary John H. Dunlap of the Society, was given at the Commercial Club, Salt Lake City, Utah, under the auspices of Engineering Council of Utah, about thirty engineers representing all branches of the Profession, being present.

ANNOUNCEMENTS

The Reading Room of the Society is open from 9 A. M. to 6 P. M., and from 7 P. M. to 10 P. M., every day, except Sundays, New Year's Day, Washington's Birthday, Memorial Day, Fourth of July, Labor Day, Thanksgiving Day, and Christmas Day; during July and August, it is closed at 5 P. M.

FUTURE MEETINGS

November 1st, 1922.—8.00 P. M.—A regular business meeting of the Society will be held, the program for which will be announced later.

ANNUAL MEETING

The Seventieth Annual Meeting will be held at the Headquarters of the Society, 33 West 39th Street, New York City, on Wednesday and Thursday, January 17th and 18th, 1923.

SEARCHES IN THE LIBRARY

As the Library of the American Society of Civil Engineers has been merged in the Engineering Societies Library, requests for searches, copies, translations, etc., should be addressed to the Director, Engineering Societies Library, 29 West 39th Street, New York City, who will gladly give information concerning the charges for the various kinds of service. A more comprehensive statement in regard to this matter will be found on page 26 of the Year Book for 1922.

NEW LOCAL SECTIONS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

The Constitutions of the following Local Sections have been approved by the Board of Direction since the list was prepared for the 1922 Year Book, pp. 41 *et seq.*:

Dayton Section (Constitution Approved by Board, 1922).

Charles H. Paul, President; K. C. Grant, Secretary-Treasurer, Winters Bank Building, Dayton, Ohio.

Lehigh Valley Section (Constitution Approved by Board, 1922).

George H. Blakeley, President; M. O. Fuller, Secretary-Treasurer, 732 Avenue H, Bethlehem, Pa.

Sacramento Section (Constitution Approved by Board, 1922).

Albert Givan, President; Joseph W. Gross, Secretary, Forum Building, Sacramento, Calif.

Toledo Section (Constitution Approved by Board, 1922).

M. J. Riggs, President; George N. Schoonmaker, Secretary-Treasurer, 716 Stickney Avenue, Toledo, Ohio.

Virginia Section (Constitution Approved by Board, 1922).

J. C. Carpenter, President; James F. MacTier, Secretary-Treasurer, 1312 Maple Avenue, Roanoke, Va.

NEW STUDENT CHAPTERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS *

The following Student Chapters have been authorized by the Board of Direction since the list was prepared for the 1922 Year Book, pp. 46 *et seq.:*

Clemson Agricultural and Mechanical College of South Carolina.

J. H. Baumann, President; W. J. Stribling, Secretary, Clemson Agricultural and Mechanical College of South Carolina, Clemson College, S. C.

Georgia School of Technology.

F. H. Harrison, President; C. M. Kennedy, Jr., Secretary, 91 West North Avenue, Atlanta, Ga.

Lehigh University.

John N. Marshall, President; George R. Swinton, Secretary, Lehigh University, Bethlehem, Pa.

North Carolina State College of Agriculture and Engineering.

H. L. Fisher, President; A. S. Gay, Secretary, North Carolina State College, Raleigh, N. C.

Norwich University.

J. H. Kane, President; Allen J. Hamilton, Secretary, Norwich University, Northfield, Vt.

Stadia Club (University of Oklahoma).

Lester W. Ellis, President; Edward W. Mars, Secretary, University of Oklahoma, 734 DeBarr Street, Norman, Okla.

University of Virginia.

T. B. Kiener, Secretary, University of Virginia, University, Va.

Worcester Polytechnic Institute.

Carl F. Meyer, President; Albert P. Hayden, Secretary, Worcester Polytechnic Institute, Worcester, Mass.

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* By a recent ruling of the Board of Direction, the minimum membership of a Student Chapter has been fixed at 12 instead of 20.

MEMBERSHIP

(From September 6th to October 3d, 1922)

ADDITIONS

HONORARY MEMBERS

		Date of Membership.
STEVENS, JOHN FRANK. Pres., Inter-Allied Technical Board, Harbin, Manchuria, China	M. Hon. M.	June 6, 1888 June 19, 1922

MEMBERS

BATES, GEORGE WHITNEY. City Engr., Lincoln, Nebr.	Assoc. M. M.	June 16, 1919 Aug. 28, 1922
BEEMER, JOHN ARTHUR. Chf. Engr., Walker River Irrig. Dist., Yerington, Nev	Assoc. M. M.	Sept. 12, 1916 Aug. 28, 1922
BOWMAN, CLARENCE HENRY. Dist. Engr., Wyoming State Highway Dept., Box 888, Casper, Wyo		Aug. 28, 1922
BROCINER, ALEXANDER. Cons. Engr., 110 West 40th St., New York City		Aug. 28, 1922
DOUGLASS, LOUIS REA. (Douglass, Corey & Fisk, Inc.), Trinidad, Colo	Assoc. M. M.	June 18, 1918 Aug. 28, 1922
FORCHHAMMER, HERLUF TROLLE. Technical Mgr., Christian & Nielsen, Victoria St., 72, London, S. W. I., England	Assoc. M. M.	Feb. 1, 1905 Aug. 28, 1922
FRANCIS, WILLIAM MORROW. Chf. Engr., Longwood, Inc., 2414 Pennsylvania Ave., Wilmington, Del		June 19, 1922
FULLENWIDER, CHARLES VICTOR ROCKWELL. Mgr., Elec. Expansion Joint Dept., The Philip Carey Co., Lockland, Cincinnati, (Res., 38 Burns Ave., Wyoming), Ohio		Aug. 28, 1922
GRIGGS, CHARLES EDWARD. City Engr., 212 East Jasper St., Tulsa, Okla.		Aug. 28, 1922
HOOPER, LEWIS GLADSTONE. Vice-Pres., L. H. Guerin Eng. Corporation, Inc., 603 Tulane-Newcomb Bldg., New Orleans, La.		Aug. 28, 1922
HULTMAN, EUGENE CHRISTIAN. Vice-Pres., Director, and Member of Executive Committee of Board of Directors, West End Street Ry., 101 Milk St., Room 810, Boston, Mass		Aug. 28, 1922
JAKOBSEN, BERNHARD FAABORG. Cons., Hydr. and Elec. Engr., 321 Rowell Bldg., Fresno, Calif	Assoc. M. M.	Oct. 9, 1917 Aug. 28, 1922
LYNCH, HENRY BAKER. Engr., Water System, City of Glendale, 1007 Van Nuys Bldg., Los Angeles, Calif		April 3, 1922
MACKEY, JOHN DERBY CORNELIUS. 231 Main St., Port Washington, N. Y.		Aug. 28, 1922
MELVILLE, JAMES HENRY STEWART. With Coverdale & Colpitts, 66 Broadway, Room 2100, New York City (Res., 331 East 7th St., Plainfield, N. J.)		Aug. 28, 1922
MOOTS, ELMER EARL. Head of Dept., Math. and Eng., Cornell Coll., 824 Summit Ave., Mount Vernon, Iowa	Affiliate Assoc. M. M.	May 31, 1916 April 17, 1918 Aug. 28, 1922

MEMBERS—(*Continued*)

Name and Address	Grade	Date of Membership.
MORE, CHARLES CHURCH. Prof. of Civ. Eng. and Head of Civ. Eng. Dept., Univ. of Washington, 4545 Fifth Ave., N. E., Seattle, Wash.	Jun. Affiliate Assoc. M. M.	May 2, 1899 Feb. 6, 1907 Mar. 31, 1908 Aug. 28, 1922
MYERS, O'KELLY WILLIAM. Div. Engr., Wm. Barclay Parsons, 1669 Forty-fourth St., Brooklyn, N. Y.		Aug. 28, 1922
ORBISON, ROBERT VANCE. City Mgr. and City Engr., City Hall, South Pasadena, Calif.		Aug. 28, 1922
REX, GEORGE EVERETT. Vice-Pres., National Lumber & Creosoting Co., 314 Railway Exchange Bldg., Kansas City, Mo.		May 8, 1922
REYNOLDS, WINCHESTER ENGLEBERT. Southern Representative, Harrington, Howard & Ash, 1012 Baltimore Ave., Kansas City, Mo.		Aug. 28, 1922
RINDSFOOS, CHARLES SIESEL. Secy-Treas., Jarrett-Chambers Co., 30 East 42d St. (Res., 126 East 19th St.), New York City	Jun. Assoc. M. M.	April 2, 1907 May 31, 1916 June 20, 1922
SINGER, ARTHUR GREGG. Surveyor and Regulator, Second Dist., Bureau of Surveys, 4661 Leiper St., Frankford, Philadelphia, Pa.		Aug. 28, 1922
SMITH, HENRY ATTERBURY. Archt., 874 Broadway, New York City.		Aug. 28, 1922
SNOWDEN, RUSSELL ELSTNER. Dist. Engr., North Carolina State Highway Comm., Kinston, N. C.	Assoc. M. M.	June 18, 1918 Aug. 28, 1922
VAN DUZER, WILLIAM ALBIE. Asst. Maintenance Engr., Pennsylvania State Highway Dept. (Res., 618 North 2d St.), Harrisburg, Pa.	Assoc. M. M.	June 30, 1911 April 4, 1922
WILSON, WILBUR M. Research Prof., Structural Eng., Univ. of Illinois, 218 Engineering Hall, Urbana, Ill.		Aug. 28, 1922

ASSOCIATE MEMBERS

Name and Address	Grade	Date of Membership.
ALLEN, JOHN MICHAEL. Engr. and Gen. Supt., Clinchfield Carbocoal Corporation of South Clinchfield, Va., 135 Washington Ave., Newark, N. J.		Aug. 28, 1922
AUSTIN, FRED HARRISON. Engr. in chg. of office, Currie Eng. Co., 1041 Second St., Webster City, Iowa		June 19, 1922
BARBER, RAY PARKER. Asst. Chf. Engr., The A. Bentley & Sons Co. (Res., 2559 Maplewood Ave.), Toledo, Ohio		Aug. 28, 1922
BETTS, CLIFFORD ALLEN. Res. Engr., Blue River Project, Denver Municipal Water-Works, 1654 Broadway, Denver, Colo.		May 8, 1922
BLAIN, CLAUD FRANCIS. Locating Engr., Public Works Dept., Sydney, New South Wales, Australia		April 3, 1922
BLANEY, HARRY FRENCH. Irrig. Engr., U. S. Dept. of Agriculture, Bureau of Public Roads, 601 Federal Bldg., Los Angeles, Calif.		Aug. 28, 1922
BOYCE, EARNEST. Asst. Engr., Kansas State Board of Health; Asst. Prof. of San. Eng., Kansas State Univ., 1703 Independent St., Lawrence, Kans.		April 3, 1922
BRAND, HARRISON, JR. 2360 Massachusetts Ave., Washington, D. C.		Aug. 28, 1922
BROCKWAY, WARNER COTTON. Asst. Engr., Bureau of Eng., Michigan Dept. of Health, Lansing, Mich.	Jun. Assoc. M.	April 14, 1919 Aug. 28, 1922
CLELAND, JOHN WILLIAMS. Asst. Chf. Engr., Southern California Gas Co., 1904 Gardena Ave., Glendale, Calif.		Aug. 28, 1922

ASSOCIATE MEMBERS—(*Continued*)		Date of Membership.
CROWLEY, WILLIAM THOMAS. City Engr., City Engr.'s Office, Lock Haven, Pa.	Jun.	Jan. 19, 1920
	Assoc. M.	Aug. 28, 1922
CUNNINGHAM, SEABORN JONES. Asst. Engr., Public Service Comm., 119 North Kensington, Kansas City, Mo.		Aug. 28, 1922
ENGLANDER, HARRY. 3801 Review Pl., New York City		Aug. 28, 1922
FRECH, HARRY EDWARD. Dist. Engr., Portland Cement Assoc., 1313 Syndicate Trust Bldg., St. Louis, Mo.		Aug. 28, 1922
GLEIM, CHARLES SAILOR. Res. Engr., New York and New Jersey Bridge and Tunnel Commissions, Hall of Records, New York City (Res., 411 Prospect St., Westfield, N. J.)		Aug. 28, 1922
GROSS, DEWITT CLINTON. Structural Engr. and Designer, 5334 Hutchinson Ave., Chicago, Ill.	Jun.	Nov. 9, 1920
	Assoc. M.	Aug. 28, 1922
HEUPERMAN, LAMBERTUS FREDERIK. Res. Engr., Oregon State Highway Comm., Box 504, Salem, Ore.		Aug. 28, 1922
HILL, GEORGE EARL. Porterfield, Wis.		April 3, 1922
HOGENTOGLER, CHESTER ALLEN. Highway Engr., Div. of Tests and Research, U. S. Bureau of Public Roads, 1819 M St., N. W., Washington, D. C.		Aug. 28, 1922
KELIHER, LESTER JOSEF NEWMAN. Mgr., Keliher Constr. Co., 308 Southern Trust Bldg., Little Rock, Ark.		Aug. 28, 1922
KERR, CHARLES MACDONALD. Engr., The Creosoted Materials Co., Inc., 301 Queen and Crescent Bldg., New Orleans, La.		Aug. 28, 1922
LAYMAN, HAROLD LESLIE. Instr., Civ. Eng., Univ. of Kansas, 1420 Ohio St., Lawrence, Kans.		Aug. 28, 1922
LOCHRIDGE, JAMES LEWIS. Office Engr., Wichita County Water Impvt., 1004 Am. National Bank Bldg., Wichita Falls, Tex.		Aug. 28, 1922
MACBEATH, DAVID LIVINGSTONE. Supt. of Constr., U. S. Bureau of Public Roads, 881 Mills Bldg., San Francisco, Calif.		Aug. 28, 1922
MCINTYRE, CLIFFORD THOMAS. Asst. Engr., City of Highland Park, 218 Colorado Ave., Highland Park, Mich.		Aug. 28, 1922
MCKENZIE, JAMES GORDON. Insp., U. S. Engr. Office, Galveston, Tex.		Aug. 28, 1922
PAHL, WILLIAM HENRY. Instr., Civ. Eng. Dept., Univ. of Nebraska, Lincoln, Nebr.		Aug. 28, 1922
PEARSON, RODERIC. Highway Bridge Engr., U. S. Bureau of Public Roads, Ogden, Utah		Aug. 28, 1922
POLLOCK, JAMES RANDAL. San. Engr., City Eng. Dept., City Engr.'s Office, Lansing, Mich.		May 8, 1922
RESMAW, CHARLES WALLACE. With Edgar T. Wheeler Co., 402 Los Angeles Ry. Bldg. (Res., 4022 Walton Ave.), Los Angeles, Calif.		Aug. 28, 1922
RHYNUS, CLARENCE PAULDING. With W. J. Sherman Co., 302 Produce Exchange Bldg., Toledo, Ohio.	Jun.	April 7, 1915
	Assoc. M.	Aug. 28, 1922
RICE, EUGENE FRANKLIN. Asst. Engr., Central Aguirre Sugar Co., Central Aguirre, Porto Rico		Aug. 28, 1922
RIESBOL, HENRY CLAY. 315 West 136th St., New York City		Aug. 28, 1922
STEVENS, HERBERT CHESTER. Supt. in Chg., Pulp Mill, Panstock Corporation, Caledonia, Nova Scotia, Canada		Aug. 28, 1922
STRAND, GUSTAVE ADOLPH. Dist. Sales Mgr., Trojan Powder Co., San Francisco (Res., 5438 Claremont Ave., Oakland), Calif.		Aug. 28, 1922

ASSOCIATE MEMBERS—(*Continued*)

Name and Address	Date of Membership.
STROUT, PHILIP STANWOOD. Asst. to Vice-Pres., Wm. Filenes Sons Co., 42 East Elm Ave., Wollaston, Mass.	May 8, 1922
WALKWITZ, CLARENCE ARTHUR. 4818 Sheridan Rd., Chicago, Ill.	Aug. 28, 1922
WEBSTER, WADE LOWE. Res. Engr., Tennessee Highway Dept., Box 27, Rogersville, Tenn.	Aug. 28, 1922

AFFILIATES

WARE, RALPH FRANKLIN. 2146 East 38th St., Los Angeles, Calif.	Aug. 28, 1922

JUNIORS

BISSCHOP, PHILIP ROWLAND ROOSEGAARDE. Care, Madera Irrig. Dist., Madera, Calif.	Aug. 28, 1922
BRYAN, RICHARD PEARSON. Res. Engr., State of Nevada Dept. of Highways, Kimberly, Nev.	Aug. 28, 1922
BUTLER, HERBERT FULLER. 20 Earle Pl., New Rochelle, N. Y.	Aug. 28, 1922
BUTLER, JOE BEATY. Asst. Prof., Civ. Eng., Missouri School of Mines, Box 547, Rolla, Mo.	Aug. 28, 1922
CASCIO, SALVATORE. 2016 Seventy-seventh St., Brooklyn, N. Y.	Aug. 28, 1922
CASEY, JOHN FRANCIS, JR. Asst. to Chf. Engr., John F. Casey Co., 935 Union Arcade Bldg., Pittsburgh, Pa.	Aug. 28, 1922
CRAIGHEAD, PHILIP BROOKS. 315 Amber St., Pittsburgh, Pa.	Aug. 28, 1922
GOERGER, GUSTAV ARTHUR. Care, Lampman, 470 Driving Park Ave., Rochester, N. Y.	Aug. 28, 1922
KHAN, ABOL FAZL. 2864 West St., Ames, Iowa	Aug. 28, 1922
LIU, YI. Second and Liu Sts., Tientsin, China	June 19, 1922
MERIWETHER, CHARLES ALBERT. Rodman, Dept. of Public Works, Bureau of Eng., 227 Warrick Lane, Lynchburg, Va.	May 8, 1922
SLOVENKO, JULIUS. Puerto Cortez, Honduras	June 19, 1922
SMITH, HARRY. Care, The H. D. Watts Co., 435 Law Bldg., Norfolk, Va.	Aug. 28, 1922
SPECHT, CASPER LAWRENCE. Civ. Engr., 616 East 4th St., Brooklyn, N. Y.	May 8, 1922
STUDDS, ROBERT FRANCIS ANTHONY. With U. S. Coast and Geodetic Survey, Box 2512, San Francisco, Calif.	Aug. 28, 1922

REINSTATEMENTS

JUNIORS

Name	Date of Reinstatement.
CHRISTIAN, VALENTINE	September 6, 1922

RESIGNATIONS

JUNIORS

Name	Date of Resignation.
JAENICKE, WILLIAM HUGO	September 6, 1922
MIAO, EN-CHAO	September 6, 1922

DEATHS

Bryson, Thomas Bines. Elected Associate Member, February 7th, 1900; died September 5th, 1922.

Hirsch, Herman David. Elected Associate Member, June 18th, 1918; died in August, 1922.

Total Membership of the Society, October 3d, 1922

Members	4 622	
Associate Members	5 235	
Corporate Members		9 857
Honorary Members		11
Juniors		461
Affiliates		170
Fellows		10
Total		10 509

ENGINEERING SOCIETIES EMPLOYMENT SERVICE

An Engineering Societies Service Bureau was established December 1st, 1918, as an activity of Engineering Council. It was managed by a board made up of the Secretaries of the four Founder Societies, and funds for its maintenance were provided by these Societies. On January 1st, 1921, this Bureau was taken over by The Federated American Engineering Societies and was known as the Employment Service of that organization. Recently, the management of the Service has been taken over by the Founder Societies. A weekly Employment Bulletin, listing the positions available, may be seen at the office of any Secretary of a Local Section. Members of the American Society of Civil Engineers who desire to register should apply for further information, registration forms, etc., to Walter V. Brown, Manager, Engineering Societies Building, 29 West 39th Street, New York City. In order to be included in the list published in *Proceedings*, copy must be received on or before the first of each month. All communications should be addressed to Mr. Brown.

EMPLOYMENT BULLETIN

POSITIONS AVAILABLE

CHEMICAL ENGINEER who has had actual experience in putting up naphthalene plants. Application by letter. Salary not stated. Location, New York City. V–1627.

STRUCTURAL STEEL DETAILER experienced in shop detailing. Application in person. Location, New York City. V–2000.

EXPERIENCED CHECKERS (2) on structural steel work. Must have had experience on buildings. Application in person. Location, New York City. V–2020.

ARCHITECTURAL DRAFTSMAN experienced on schoolhouses. Application in person. Location, New York City. V–2047.

STRUCTURAL STEEL DETAILERS AND CHECKERS (5). Must be experienced men. Application in person. Location, New York City. V–2054.

CONCRETE DRAFTSMAN on industrial building work. Must be capable of laying out concrete work. Application in person. Location, New York City. V–2073.

HIGH-GRADE SALES EXECUTIVE with broad knowledge of industrial field to carry on an educational industrial campaign among manufacturers; complete details required. Application by letter. Headquarters, New York City. V–2097.

SALES ENGINEERS, three of whom are to possess the qualifications requisite to apply gas-fired steam boilers in industries and also for house heating; one for application of gas-fired appliances for heat treatment of metals; and one to possess qualifications for application of gas to gas-burning equipment to large bake ovens. Application by letter. Location, New York City. V–2116.

ASSOCIATE EDITOR with plant engineering experience. Application by letter, stating age, education, and experience. Must have editorial and plant management experience. Salary not stated. Location, New York City. V–2117.

CIVIL ENGINEER experienced on road construction, setting grades, etc. Application by letter. Location, New York City. V–2144.

STRUCTURAL STEEL DRAFTSMAN (1 or 2) on design and checking in connection with architectural plans. Must be experienced. 6 to 8 weeks' work. Application in person. Location, New York City. V–2163.

FOREMAN in dry press shop. At present, department employs from 40 to 50 persons. Must have had experience in dry-pressing of porcelain. Position eventually leads to superintendency of plant. Age 30 to 35; technical education not essential, but experience is necessary. Application by letter. Salary depends on experience of applicant. Location, Ill. V–2179.

CIVIL ENGINEERS (3) experienced on highway construction to act as sales promotion experts among State commissioners, engineers, and contractors. Application by letter. Salary not stated. Location, Ohio. V–2180.

HIGH-GRADE DESIGNER experienced along the lines of adding and calculating machines, typewriters, type-setting machines, or similar apparatus. Application in person. Salary not stated. Location, New Jersey. V–2186.

CONSTRUCTION SUPERINTENDENT on reinforced concrete manufacturing building or wood frame office buildings. Three or four years' experience on construction work, in charge of men. Application by letter. Salary not stated. Location, Penna. V–2187.

ARCHITECTURAL DRAFTSMAN for residential and alteration work. Man familiar with New York building rules and having 2 to 3 years' experience. Application in person. Location, New York. V–2190.

SALESMAN with knowledge of coal combustion for heating and power plant, to sell fuel economy apparatus, designed to burn buckwheat coal and screenings in plants where larger and more expensive coal is used. Application in person. Commission basis. Location, Philadelphia, Pa. V–2191.

APPRENTICE AND ASSISTANT TEST ENGINEERS, mechanical engineering graduates, for testing turbines, pumps, condensers. Central station plants. Application by letter. Location, Penna. V–2196.

FOREMAN of die and machine shop with knowledge of special porcelain dies. Shop employs 12 men. Application by letter. Location, Illinois. V–2204.

TIME STUDY ENGINEER with about five years' experience. Duties will be on loading and other labor problems. Application by letter, stating age, experience, etc. Salary not stated. Location, New York City. V–2214.

COAL, OIL AND NATURAL GAS ENGINEERS for report and research work in Government departments. Application by letter. Salary depends on experience. Location, Washington, D. C. V–2215.

STRUCTURAL DRAFTSMAN, two years' experience. Temporary until Civil Service examination is taken, and if passed, position will be permanent. Application in person. Location, New York City. V–2236.

EXPERIENCED ESTIMATOR, thoroughly posted on reinforced concrete and general building work. Only those having had at least two years' experience with one of the large construction companies will be considered. Application by letter only. Location, New York City. V–2258.

DRAFTSMAN for building construction on schools and churches. Application by letter, stating age, education and experience. Only engineers with this experience considered. Location, Penna. V–2266.

DESIGNER on structural steel and reinforced concrete buildings, bridges, etc. Temporary position, 6 months. Application by letter, giving age, education, and experience. Salary not stated. Location, Cuba. V–2269.

AGENTS to handle sale and installation of Newport Rotary Oil Burner, an oil burner burning efficiently 11° Baumé Mexican oil for high and low-pressure steam and hot-water boilers. Exclusive territory granted. Application by letter. Salary not stated. Headquarters, Rhode Island. V–2274.

ENGINEER to organize and take charge of district promotional and educational work on use of lime in building, agriculture, and chemistry. Work will be field work. Must have business experience in organization, sales and executive capacities, initiative, adaptability, common sense, perseverence, good address, and ability to co-operate. Application by letter. District headquarters, St. Louis, Mo. National headquarters, Washington, D. C. V–2278.

YOUNG ENGINEER, Electrical or mechanical, experienced in the use and application of auxiliary for high-pressure, modern, steam power plants. Ability to write advertising copy and prepare technical articles for press essential. Company manufactures electrical valve-control equipment used exclusively on steam lines in large power stations and also complete line of valve-control apparatus for water-works and power stations. Will also act as research engineer for new fields for control and must possess sufficient business and engineering knowledge to carry on work without supervision. Prefer married man, age not over 35 or 40, already in a similar position. Application by letter. Salary not stated. Location, Conn. V–2302.

ENGINEER capable of doing some editorial work for *Marine Review*. Some practical experience at sea, in shipyards, or preferably in office of well organized ship-operating company desirable. Should have had at least five years' practical experience. Experience as technical journalist desirable, but not necessary. Ability to write absolutely essential. Must be familiar with American shipping. Application by letter. Location, Ohio. V–2308.

SALESMEN capable of rapid development into Branch Managers, some traveling necessary, but only on short trips in near-by territory. Automobile experience preferred. Application by letter. Salary and commission basis. Location, Ohio. V–2313.

DESIGNER, experienced on centrifugal pumps or velocity machines and reciprocating pumps, engine work, or allied lines. Application by letter, stating education, experience, age, physical characteristics, compensation required, and when available, in handwriting. Salary not stated. Location, Mass. V–2328.

DRAFTSMEN experienced in building design. Must be able to handle both concrete and steel for large automobile plant. Application by letter, stating age, salary, and date available. Salary not stated. Location, Michigan. V–2330.

DRAFTSMEN with some knowledge of pipe layouts. Application by letter. Salary not stated. Location, Penna. V–2343.

STEEL AND REINFORCED CONCRETE DRAFTSMAN experienced on flat slab work. Application in person. Location, New York City. V–2349.

ESTIMATOR to take off reinforced steel, metal lathe, steel tile, steel lumber. Experienced man only. Application in person. Location, New York City. V–2352.

SALES REPRESENTATIVES for new concern manufacturing steam turbines. Preference given to men having one of the following qualifications: (1) Graduate mechanical or electrical engineer; (2) Experienced in steam turbine design, manufacture or sales; and (3) Established as representative at present of some other concern selling pumps or power-plant contractor. Application by letter, giving qualifications and references. Commission

basis. Location, Philadelphia, Pittsburgh, Cleveland, Chicago, New Orleans, Kansas City, and St. Louis territories. Headquarters, New York State. V–2358.

TOPOGRAPHICAL DRAFTSMAN. Work will consist of taking field notes, making necessary calculations, plotting, and tracing. Transportation paid from port of sailing. Board about $30 per month. Should be single, or, if married, be willing to go without family. Application by letter. Location, Guatemala. V–2359.

ARCHITECTURAL DRAFTSMAN with experience on factory construction. Application in person. Salary not stated. Location, Northern New Jersey. V–2367.

ENGINEER to represent company in making contracts with industrial concerns for installation of a training program for foremen. Must have selling experience. Part-time basis considered. Application by letter. Commission basis. Location, New York City. V–2379.

ERECTION ENGINEER experienced on general machine erection to handle installation of industrial ovens. Application in person. Location, Traveling. V–2387.

ARCHITECTURAL DRAFTSMAN, A-1, who must be an excellent letterer. American citizen and citizen of New York State. 3 to 4 weeks' work. Application in person. Location, New York. V–2388.

SALES ENGINEERS (2) to sell lubricating oils, cutting oils, and like products to industrial plants. Prefer man with from one to two years' experience on specialties sold to engine room. Should be sufficiently familiar with machinery and plant conditions to influence oil specifications at this source. Application in person. Expenses paid, with commission arrangement based on salesman's net profits. Location, New York District. V–2404.

SAFETY ENGINEER. Application by letter. Location, New York State. V–2408.

DESIGNER for textile dryers. Engineer must have this experience. Application by letter, stating age, education, and experience. Application by letter. Salary not stated. Location, New England. V–2409.

ASSISTANT SUPERINTENDENT, young man between ages of 25 and 30. Must be able to handle tools necessary to make minor repairs on machinery, piping, conveyors, etc., keep records of material and production, and in general fit himself to take over position of superintendent when vacancy occurs. Application by letter only, giving full details as to experience and qualifications. Salary small until ability is demonstrated. Location, New Jersey. V–2427.

CHIEF DRAFTSMAN to take charge of details. General structural steel experience and also some house experience. Application in person. Location, New York. V–2434.

COMBUSTION ENGINEER AND SALES, mostly sales. Acquaintance with New York City and State of New Jersey. 30 to 37 years old. Application by letter. Salary depends on man. Location, New York City. V–2437.

CIVIL ENGINEERS (3) for work in Santo Domingo, consisting mostly of field work. Should be capable of taking charge of a party under general direction of an engineer now on work; another to be an assistant to bring up levels in contour work, etc. Salaries will depend on experience, etc. Application in person. Salary not stated. Transportation is furnished; also board and lodging while men are working in field. V–2443.

YOUNG CIVIL ENGINEER eventually to become head of Civil Engineering Department. Must have ability to direct work of field parties engaged on surveys for hydro-electric projects and transmission lines, and also sufficient knowledge of general building and other construction to design and carry on necessary general maintenance, other than electrical, of properties of various companies consisting of hydro-electric generating stations, substations, gas works, water-works, and street railway. Application by letter. Location, New York State. V–2453.

CONSTRUCTION ENGINEER specializing in line of oil mills for extracting oil from olive husks by means of carbon sulphide (or any other solvent that gives better results than sulphide), including installation of soap plant, complete refinery (neutralization, deodorization, and decoloring). Application by letter. Salary not stated. Location, Mahdia, Tunis. V–2458.

ESTIMATOR AND DESIGNER on reinforced concrete structures, docks, and piers. Should be technical graduate, between ages of 25 and 30. Application by letter. Salary not stated. Location, New York City. V–2459.

INSPECTOR for excavation work. Recent graduate. Application in person. Temporary position, possibly working into permanent one. Location, New York City. V–2460.

SUPERINTENDENT for office building. Experienced man about 35 to 40 years old. Application in person. Location, New York City. V–2461.

ENGINEERS (6) with sales experience to handle new style grate for burning barley coal. Application in person. Commission basis. Location, New York City. V–2491.

RECENT GRADUATES. One with two years' experience, holding either chemical, mechanical, electrical, or civil degrees. Would enter refinery practically as students for general refinery work which would permit a close observation of qualifications and aptitude so that later might be placed where there would be real chance for service. Application by letter. Location, New Jersey. V–2497.

YOUNG MECHANICAL ENGINEER with training in economics as well as engineering. Practical experience in factory production and management essential, also sympathetic understanding of American labor movement. Desired for research and preparation of briefs, reports, exhibits, etc., chiefly in field of industrial relations. Application by letter, submitting complete statement of qualifications. Salary not stated. Location, New York City. V–2498.

ENGINEER experienced in reinforced concrete design applying to heavy work required in foundations for deep condenser pits, and work of that nature. Application by letter. Salary not stated. Location, New York City. V–2499.

DESIGNERS on structural steel for buildings. Experience on shop details. Application by letter. Salary not stated. Location, New York City. V–2502.

SALES ENGINEER, to sell industrial paint of unique qualities. Possibility of handling other interesting lines. Sales experience not necessary. Good proposition for recent graduate wishing to enter sales game. Application in person by appointment. Commission basis. Headquarters, New York City. V–2504.

SALES REPRESENTATIVES to represent gas and oil-burning equipment company in United States. Application by letter. Salary not stated. V–2513.

SALES ENGINEER, young, single man having one or two years' practical experience for exploiting sale of a line of industrial equipment in New England and Middle Atlantic States. Application by letter, stating age, experience, and salary expected. Headquarters, New York City. V–2517.

SALES ENGINEER to sell crushing and grinding machinery. Application in person. Commission basis. Location, New York City. V–2522.

TOPOGRAPHICAL DRAFTSMEN, experienced in topography and map drafting. Must be good letterers. Railroad work. Application by letter. All expenses. Location, Tenn. V–2533.

CONCRETE INSPECTORS (3), must have at least four years on heavy concrete work. Single men. Application in person. Transportation. Location, Alabama. V–2542.

LABORATORY MAN, experienced in testing concrete briquettes. Application in person, New York City. Transportation paid. Location, Alabama. V–2543.

ARCHITECTURAL DRAFTSMAN able to make working drawings from sketches, any details necessary filing in city departments, etc. Application in person. Location, New York City. V–2546.

ENGINEER with advertising or catalogue writing experience. Application by letter, stating age, education, and experience in detail. Salary not stated. Location, New York State. V–2548.

ENGINEER familiar with light structural steel erection within a plant, also structural steel assembling for small machinery, such as blowers and heating units. Resident of Elizabeth, N. J., preferred. Temporary. Application in person. Salary not stated. Location, New Jersey. V–2551.

DRAFTSMAN with structural steel experience. Application in person. Location, New York City. V–2563.

DRAFTSMAN with timber experience. Application in person. Location, New York City. V–2566.

ARCHITECTURAL MEN to take off quantities and build up materials for railroad buildings, then to apply prices to the built-up materials. Application in person. Location, New York City. V–2567.

CHIEF DRAFTSMAN experienced on reinforced concrete factory buildings. Need not necessarily be a designer, but must be able to run office. Application in person. Location, New Jersey. V–2570.

COST CLERK competent to keep track of cost of production of sugar in raw sugar factory that has in conjunction with it a refinery and distillery. Living quarters provided if married, and room if single. Would have to purchase food, or board. Best of food or board would be somewhat less than if purchased in New York City. Will be sent to plant sometime in November. Application by letter. Headquarters, New York City. Location, Philippine Islands. V–2573.

ARCHITECTURAL DRAFTSMAN with good academic training. No previous practical experience necessary. Application in person. Location, New York City. V–2575.

ENGINEER experienced in the design, operation, and sale of insulating materials in connection with installations of all forms of drying apparatus, such as textile dryers, tentering frames, leather dryer, dryers used in chemical processes, and will also enter field of japanning ovens, as used in automobile and metal industry. Must have had thorough sales experience in addition to the necessary technical training. Application by letter stating age, education, and experience in detail. Salary not stated. Location, Penna. V–2576.

MAINTENANCE ENGINEER with millwright experience. Application by letter. Location, New York City and vicinity. V–2577.

ENGINEERS AND DRAFTSMEN for central office, engineering division, for men with college training in engineering or the physical sciences. Practical telephone experience may substitute. Draftsmen who have had technical high school training and from 2 to 4 years' drafting experience. Application by letter. Salary not stated. Location, Illinois. V–2578.

DRAFTSMAN for sugar mill. Prefer young man recently graduated from college or architectural or engineering school, who could be classed as good draftsman. Working knowledge of Spanish desirable. Application by letter. Board and lodging furnished on estate by employer; transportation from New York to plantation given. Headquarters, New York City. Location, Cuba. V–2580.

STRUCTURAL ENGINEER thoroughly trained in design of structural steel and reinforced concrete for buildings. One who can write specifications and attend to supervision preferred. Application by letter. Salary not stated. Location, Arkansas. V–2581.

ENGINEER experienced in road building and handling of crushed stone, to call on firms to investigate the market in Illinois with view of opening a lime quarry. Application by letter. Salary not stated. Location, Illinois. V–2611.

DRAFTSMAN familiar with power plant, water supply, and architectural work. Must speak Spanish. Salary not stated. Application by letter. Location, South America. V–2618.

ARCHITECT experienced in general design, office, industrial, and municipal buildings. Must speak Spanish. Application by letter. Salary not stated. Location, South America. V–2619.

CHIEF DRAFTSMAN to take charge of drafting office. Must speak Spanish. Application by letter. Salary not stated. Location, South America. V–2621.

COST ENGINEER experienced in general contracting cost work; also cost plus basis system for municipal work. Must be able to establish cost system for contractor's office. Spanish desirable. Application by letter. Salary not stated. Location, South America. V–2622.

MEN AVAILABLE

STRUCTURAL ENGINEER, Assoc. M. Am. Soc. C. E.; age 38; married. Fourteen years in miscellaneous engineering, including large steel plant construction, ice plants, industrial plants, capable of taking responsible charge of purchase and arrangements of equipment, structural design, power requirements, specifications, and contracts. CE–360.

EXECUTIVE ENGINEER, with sales, advertising, and marketing experience. Technical work required knowledge of structural, highway, steam and electric railway engineering; valuation, correspondence, reports, economics, general business and industry, and physical metallurgy. Good address; age 38. Professional practice and Chicago location preferred. CE–361.

CIVIL ENGINEER is open for responsible executive position; college graduate. Twenty years' practical experience in design and construction work of all kinds; thoroughly conversant with appraisal work, the preparation of reports and financial statements, and the analysis of general business conditions, in regard to engineering projects. Highest technical and business references. CE–362.

CIVIL ENGINEER, Univ. of Pennsylvania; age 30. Eight years' experience including railroad construction, design, and maintenance, steel mill layout and construction, triangulation and topography, roads, bridges, and wharves. Permanently located at present, but desires change to something leading up to an executive position. Location immaterial. Speaks French and little Spanish. CE–363.

OFFICE AND FIELD ENGINEER; technical graduate; age 33; married. Nine years' experience along administrative and executive lines, covering field superintendence, special investigations, and reports, employment and statistical work; desires position in construction, industrial, or manufacturing fields. CE–364.

GRADUATE CIVIL ENGINEER AND CONSTRUCTION SUPERINTENDENT; Assoc. M. Am. Soc. C. E.; age 34; degree 1908. Twelve years' experience, roads, bridges, surveys, sewers, water-works, and concrete industrial buildings. Experience includes design, inspection, and superintendence. Two years in charge of war work for Construction Division, U. S. A. Available at once. Location immaterial. CE–365.

CONSTRUCTION ENGINEER, Cornell graduate, with street railway, power plant, hydro-electric, and industrial building experience; also, power-plant design. CE–366.

CIVIL ENGINEER, M. Am. Soc. C. E., and other organizations, desires working partnership or permanent employment; high-grade technical and academic education; complete office and field equipment; 25 years' successful practice, water supply, sewerage, garbage disposal, pavements, steam and hydro-electric plants, and other construction; city engineer for several hundred thousand population; active; good health; personal interview New York City or vicinity. CE–367.

MINUTES OF MEETINGS

OF THE SOCIETY

October 4th, 1922.—The meeting was called to order at 8:10 P. M.; J. Waldo Smith, M. Am. Soc. C. E., in the chair; C. E. Beam, acting as Secretary; and present, also, 134 members and guests.

The minutes of the meeting of September 6th, 1922, were approved as printed in *Proceedings* for October, 1922.

The following deaths were announced:

THOMAS BINES BRYSON, of New York City, elected Associate Member, February 7th, 1900; died September 5th, 1922.

HERMAN DAVID HIRSCH, of Cape Town, South Africa, elected Associate Member, June 18th, 1918; died in August, 1922.

A paper entitled "Experiments with Models of the Gilboa Dam and Spillway", by R. W. Gausmann and C. M. Madden, Associate Members, Am. Soc. C. E., was presented by Mr. Gausmann, who illustrated his remarks with lantern slides.

A paper by Charles P. Berkey, Esq., and James F. Sanborn, M. Am. Soc. C. E., entitled "Engineering Geology of the Catskill Water Supply" was presented by Mr. Sanborn, who also illustrated his remarks with lantern slides.

The meeting was then opened to discussion which was participated in by Messrs. Lazarus White, William W. Brush, Walter E. Spear, Arthur S. Tuttle, Thomas H. Wiggin, who illustrated his discussion with lantern slides, Louis L. Tribus, E. G. Haines, X. Henry Goodnough, and J. Waldo Smith. Written discussion on the paper by Messrs. Berkey and Sanborn, by Alfred D. Flinn, M. Am. Soc. C. E., was announced.

Adjourned.

NEW BOOKS*

(From September 1st to September 30th, 1922)

The statements made in these notices are taken from the books themselves, and this Society is not responsible for them.

DONATIONS TO ENGINEERING SOCIETIES LIBRARY

PROPERTIES OF ELECTRICALLY CONDUCTING SYSTEMS.

By Charles A. Kraus. (American Chemical Society. Monograph Series.) N. Y., Chemical Catalog Co., 1922. 415 pp., diagrams, 9 x 6 in., cloth, $4.50.

The author here presents a comprehensive, systematic account of the more important conclusions reached by the study of ionic phenomena, which have hitherto been available only in scattered form, in periodicals and transactions of scientific societies. His book affords a convenient summary of the contemporary understanding of the subject, useful both to those directly engaged in studying it and to investigators in allied sciences.

ELEMENTARY DETERMINANTS FOR ELECTRICAL ENGINEERS.

By Herbert P. Few. Lond., S. Rentell & Co., Ltd.; N. Y., D. Van Nostrand Co., 1922. 98 pp., 7 x 5 in., cloth. $1.50.

This material appeared originally as articles in *Electricity*, the aim of the author being to emphasize the advantages that the methods of determinants possess over ordinary algebraic processes for solving many types of problems of interest to electrical engineers. Examples are given dealing with testing, telephony, telegraphy, power distribution, cable balancing, etc.

DICTIONARY OF APPLIED PHYSICS.

Edited by Sir Richard Glazebrook. Vol. 2, Electricity. Lond., Macmillan and Co., Ltd., 1922. 1 104 pp., illus., 9 x 6 in., cloth. $15.00.

The second volume of this important reference work contains many articles of importance to electrical engineers and physicists. Some of the longer articles are: Photoelectricity, by H. Stanley Allen; Technical Applications of Electrolysis, by A. J. Allmand; Arc Lamps, by R. E. Angold; Positive Rays, by F. W. Aston; Insulated Electric Cables, by C. J. Beaver; Switchgear, by R. A. R. Bolton; Capacity and Inductance, by Albert Campbell; Batteries, by W. R. Cooper; Electrons, by J. A. Crowther; Magnetic and Radio-Frequency Measurements, by D. W. Dye; Molecular Theories of Magnetism, by Kotaro Honda; Telephony, by F. B. Jewett; Magnet Design, by R. L. Jones; Stray-Current Electrolysis, by Burton McCollum; Thermionics, by O. W. Richardson and W. Wilson. Numerous bibliographies and a full index are provided.

ELEKTROTECHNIK.

Von J. Herrmann. Pt. 1, Die physikalischen Grundlagen. Vierte Auflage. (Sammlung Göschen.) Berlin, Vereinigung wissenschaftlicher Verleger, Walter de Gruyter & Co., 1922. 125 pp., plates, diagrams, 6 x 4 in., boards.

This is the first of four volumes intended as an introduction to heavy current engineering and is confined to the physical principles involved. The information is presented concisely, definitely, and without undue use of mathematics.

GRUNDZUGE DER ANGEWANDTEN ELEKTROCHEMIE.

Von Georg Grube. Bd. 1, Elektrochemie der Lösungen. Dresden und Leipzig, Theodor Steinkopff, 1922. 268 pp., illus., diagrams, 9 x 6 in., paper. $1.68.

The "Principles of Electro-chemistry", of which this is the first volume, is intended to meet the need for a brief textbook of practical electro-chemistry in which special attention is given to technical applications. This volume contains the theoretical information necessary for a fruitful discussion of technical electro-chemical processes and discusses the electro-chemistry of solutions. It includes electro-metallurgical processes in solutions, the electrolysis of alkali chloride solutions, electrolytic oxidation processes, the electrolysis of water, and electrolytic reduction processes.

MASTERING POWER PRODUCTION.

By Walter N. Polakov. N. Y., Engineering Magazine Co., 1921. 455 pp., pl., diagrams, 9 x 6 in., cloth. $5.00.

* Unless otherwise specified, books in this list have been donated by the publishers.

The subject of this volume is the technology of a method of mastering power production so that the best use of resources will be made under present social, economic, and political conditions. Mr. Polakov avoids discussion of the technical subjects already available in books on power engineering, and confines himself to the broader economic, psychological, and engineering features. Special attention is given to management problems. Contents: The Descent of the Principle of Production for Use; The Power Industry as an Economic Factor; The Location of Plants; The Equipment of Plants; Mastering Materials; Mastering Maintenance; Mastering Labor Problems; Mastering Processes; Mastering Records; The Analysis of Expenses; Power as a Commodity.

POWER ALCOHOL.

By G. W. Monier-Williams. (Oxford Technical Publications.) Lond., Frowde, 1922. 323 pp., illus., diagrams, 8 x 5 in., cloth. $7.00.

The author has given in this volume a complete, well-balanced account of all the problems—engineering, chemical, and economic—associated with the production and utilization of alcohol as a motor fuel.

MODERN WORKSHOP PRACTICE.

By Ernest Pull. Sixth Edition. N. Y., D. Van Nostrand Co., 1922. 671 pp., pl., illus., diagrams, tab., 8 x 6 in., cloth. $5.00.

A textbook for students and machinists' apprentices. Deals with the common bench and machine tools, gauges, lathes, lathe tools and fixtures, milling machines, planers, boring and slotting machines, and grinding machines. The author describes methods of bench work, heat treatment, soldering and brazing, twining, screw-cutting, gear-cutting, planing, shaping, drilling, and forging.

MACHINE TOOL OPERATION.

By Henry D. Burghardt. Pt. 2, Drilling Machine, Shaper and Planer, Milling and Grinding Machines. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. 438 pp., illus., diagrams, 8 x 5 in., cloth. $2.75.

This volume is intended as a textbook for trade schools and apprentices, and follows one on lathe, bench, and forge work. The text treats of drilling, shaping, planing, milling, and grinding machines, emphasis being laid on the fundamental principles of their construction and operation. These principles are discussed thoroughly, as a foundation for rapid production.

GRADUATING, ENGRAVING, AND ETCHING.

(Machinery's Blue Books.) N. Y., Industrial Press; Lond., Machinery Publishing Co., 1921. 60 pp., illus., diagrams, 9 x 6 in., paper. 50 cents.

The methods presented in this pamphlet are those commonly used by manufacturers of tools and instruments to graduate straight and circular scales and to engrave or etch name plates, etc. The dividing engines and engraving machines available are described, and their use is explained.

DIE-CASTING.

(Machinery's Dollar Books.) N. Y., Industrial Press; Lond., Machinery Publishing Co., 1921. 108 pp., illus., diagrams, 9 x 6 in., paper. $1.00.

The author describes briefly the development of die-casting machines, their commercial applications, and the alloys used for die-casting. These descriptions are based on contributions to *Machinery*, and are intended for those engaged in die-casting.

BEARINGS AND BEARING METALS.

(Machinery's Dollar Books.) N. Y., Industrial Press; Lond., Machinery Publishing Co., 1921. 120 pp., illus., diagrams, 9 x 6 in., paper. $1.00.

A book of practical information upon plain bearings, in which the various types are shown and their suitability for various purposes explained. Information is also given on the composition and properties of bearing metals, the service to which they are adapted, and proper methods of lubrication.

ENGINES AND BOILERS.

By Thomas T. Eyrie. N. Y., The Macmillan Co., 1922. 234 pp., diagrams, 9 x 6 in., cloth. $3.50.

An elementary course in heat engines for students of engineering, based on the author's experience in teaching engines and boilers and allied subjects at Purdue University.

20TH CENTURY GUIDE FOR DIESEL OPERATORS.

By Julius Rosbloom and Orville R. Sawley. Seattle, Western Technical Book Co., 1922. 637 pp., port., illus., diagrams, 9 x 6 in., cloth.

The authors have attempted to furnish in compact form a summary of present-day knowledge of Diesel engines and their auxiliary machinery. The information given is presented in a form suited to the needs of those in charge of power plants and covers both land and sea operation. Many commercial types of engines are described. One chapter is devoted to low-compression or "semi-Diesel" engines.

AMERICAN FUELS.

By Raymond Foss Bacon and W. A. Hamor. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. 2 vol., illus., diagrams, 9 x 6 in., cloth. $12.00.

The editors of this volume have attempted to condense into a series of especially prepared chapters the fruits of the experience of specialists, and thus present an authoritative account of all American fuels of technical importance. It is intended to give informative summaries of sound practice and provide such information as will assist the engineer to decide on the most suitable fuel to use or the changes to make in using fuel or heat in order to get the highest efficiency in plant operation.

LIQUID FUEL AND ITS APPARATUS.

By Wm. H. Booth. Second Edition. N. Y., E. P. Dutton and Co., 1922. 308 pp., illus., diagrams, 9 x 6 in., cloth. $4.00.

The object of this book is to present in a handy form the more practical points of the author's larger book, "Fuel and Its Combustion". The present book is fairly closely confined to the use of liquid fuel under boilers and in internal combustion engines. It discusses the principles of liquid fuel and the properties of fuel oils, gives examples of practice in using oil fuel for stationary boilers, locomotives, and oil engines, and discusses burners and the storage, distribution, and atomizing of oil.

DIE WARME=EIN GAS.

Von Lothar Fischer. Leipzig, H. A. Ludwig Degener, 1922. 61 pp., 9 x 6 in., paper. 38 marks.

This pamphlet is an attack on current opinion concerning the nature of heat. Heat is, according to this author, a gas. This gas he conceives as having an atomic weight far below that of hydrogen, and molecules of such minuteness that they diffuse easily through all substances. His monograph presents reasons for this opinion.

BEITRAG ZUR BERECHNUNG DER DAMPFTURBINEN AUF ZEICHNERISCHER GRUNDLAGE.

Von Erich Henne. (Forschungsarbeiten auf dem Gebiete des Ingenieurwesens. Heft. 260). Berlin, Julius Springer, 1922. 58 pp., diagrams, chart, 10 x 7 in., paper. 20 marks.

Describes a simplified method of determining the dimensions of the stages of a turbine, for any given efficiency, by means of graphic charts. The charts are given in the book, with examples of their use. They are based on the relation between the indicated efficiency, speed of revolution, and the heat drop discovered by Loschge. By use of the charts, the author claims, much wearisome calculation can be avoided without any loss of accuracy.

CONSERVATION OF NATURAL GAS IN KENTUCKY.

By Willard Rouse Jillson. Louisville, Ky., John P. Morton & Co., 1922. 152 pp., illus., 8 x 5 in., cloth.

Dr. Jillson's little book is intended to call the attention of those interested in Kentucky to the urgent necessity of conserving the natural gas reserves of the State, and to indicate the necessary steps to prevent waste. Incidentally, the book provides a good summary of the gas resources and industries of Kentucky. It should prove valuable both to producers and consumers of gas, by calling attention to the consequences of waste, and by its specific recommendations for conservation.

COAL TRADE.

By Sydney A. Hale. Forty-eighth Annual Edition. N. Y., Estate of F. E. Saward, 1922. 254 pp., 8 x 6 in., cloth. $3.00.

A statistical and economic review of the coal and coke industry during 1921. Figures and information concerning production, prices, market conditions, exports, and imports, for anthracite, coke, briquettes, and bituminous coal are presented; miscellaneous transportation statistics of interest to dealers in coal are given, and export trade is discussed.

RAPPORTS DES INGENIEURS DES MINES SUR LA SITUATION DES MINES

En 1919 et 1920. Published by Comité Central des Houillères de France. Paris, 1922. 237 pp., tab., 11 x 9 in., paper.

The two reports that make up this volume, give an extended account of coal mining operations in France during 1919 and 1920. Tables show the output, prices, number of workers, accidents, etc., for the mines in each district.

SPACE—TIME—MATTER.

By Hermann Weyl. N. Y., E. P. Dutton & Co., 1922. 330 pp., diagrams, 9 x 6 in., cloth. $7.50.

Although many popular introductions to the general theory of relativity have appeared, systematic presentations are not common, and for this reason this translation of the leading German work on the subject is welcome. In it are given all the details of the mathematical reasoning required for a thorough understanding of the subject. The author's extension of the theory to include electromagnetic phenomena is given in full.

SIX-PLACE TABLES.

N. Y. and Lond., McGraw-Hill Book Co., 1922. 124 pp., 7 x 4 in., fabrikoid. $1.25.

This volume contains a selection of tables of squares, cubes, square roots, cube roots, fifth roots, and powers, circumferences and areas of circles, logarithms of numbers, logarithms of trigonometric functions, and natural trigonometric functions, arranged to meet the need for a volume of pocket size, containing the tables in regular, continuous use by students and engineers.

TREATISE ON BESSEL FUNCTIONS.

By Andrew Gray and G. B. Mathews. Second Edition. Lond., Macmillan & Co., 1922. 327 pp., 9 x 6 in., cloth. $12.00.

This book has been written in view of the great and growing importance of the Bessel functions in almost every branch of mathematical physics; and its principal object is to supply in a convenient form so much of the theory of functions as is necessary for their practical application, and to illustrate their use by a selection of physical problems, worked out in some detail. This new edition has been thoroughly revised. The earlier chapters have been rewritten, examples have been appended, and additions have been made to the tables. A bibliography is included.

LES AXIOMES DE LA MECANIQUE.

Par Paul Painlevé. (Les Maitres de la Pensée Scientifique.) Paris, Gauthier-Villars et Cie., 1922. 111 pp., 7 x 5 in., paper.

In this small book, Prof. Painlevé sets forth, with a minimum of mathematical terminology, the axioms of mechanics, as laid down by the founders of the science. From these he proceeds to a description of the modifications proposed by recent theories. His book is, therefore, not only a thorough study of the fundamental axioms of the subject, but also an introduction to the theory of relativity.

FACTORY STORESKEEPING.

By Henry H. Farquhar. N. Y. and Lond., McGraw-Hill Book Co., 1922. 182 pp., illus., 9 x 6 in., cloth. $2.50.

The materials considered in this book are the stores of raw materials and factory supplies, worked materials or work in process, and partly or completely finished parts. The book deals with the replenishment, storage, and disbursement of these two classes of materials, but excludes the administration of work in process. The author outlines the principles and methods by which this problem may be solved and a system may be developed to suit local conditions, but he does not outline a system for any specific type of factory.

GRAPHIC CHARTS IN BUSINESS.

By Allan C. Haskell. N. Y., Codex Book Co., 1922. 250 pp., charts, 9 x 6 in., cloth. $4.00.

A companion volume to the author's earlier book, "How to Make and Use Graphic Charts". The present work is confined to charts generally used for business purposes, line, bar, circular percentage, organization, trilinear, and probability charts. Methods of making these charts are explained, their adaptability for various purposes is set forth, and their application in various departments of business organizations illustrated. The ratio chart is explained fully. A bibliography is included. The book is intended to help the man of business see when and how graphic charts can serve his purposes in controlling business operations.

CHEMISTRY AND TECHNOLOGY OF GELATIN AND GLUE.

By Robert Herman Bogue. N. Y. and Lond., McGraw-Hill Book Co., 1922. 644 pp., illus., diagrams, 9 x 6 in., cloth. $6.00.

Reliable information on the manufacture, testing, analysis, and general applications of gelatin and glue has been difficult to obtain by students and investigators, and information on the chemistry of these substances has been even scarcer. The author has attempted to meet these wants, and particularly to correlate and summarize the work done during the past decade on the chemistry of gelatin. His book is directed toward the chemist and research student, rather than the plant technologist, but contains much of interest to the latter.

PRACTICAL ACCOUNTING FOR GENERAL CONTRACTORS.

By H. D. Grant. N. Y. and Lond., McGraw-Hill Book Co., 1922. 254 pp., forms, 9 x 6 in., cloth. $3.00.

The author states that, although many excellent books on general accounting exist, as well as many on accounting in various industries, little has been written to fit the needs of the contractor. He has prepared therefore this description of a system which will enable the contractor to co-ordinate and control his operations so that the status of his contracts may be ascertained at all times.

RAILWAY ELECTRIC TRACTION.

By F. W. Carter. N. Y., Longmans, Green & Co.; Lond., Edward Arnold & Co., 1922. 412 pp., diagrams, 9 x 6 in., cloth. $8.50.

This book discusses the methods of electric traction as applied to railways and expounds methods of technical calculation applicable to the subject. In pursuance of the first objective, the author attempts to determine what constitutes good practice and why. The methods of calculation described are for the most part the author's own. The work affords a broad view of the principles underlying electric railways, unencumbered by superfluous descriptive matters.

MOSQUITO ERADICATION.

By W. E. Hardenburg. N. Y. and Lond., McGraw-Hill Book Co., 1922. 248 pp., illus., 9 x 6 in., cloth. $3.00.

This book contains a concise account of the injury done by mosquitoes, the varieties found in America, the development of control measures, and current practice in mosquito control. Directions for organizing and administering campaigns are given, as well as information concerning the necessary engineering and other measures of most value.

TEXTBOOK OF THE MATERIALS OF ENGINEERING.

By Herbert F. Moore. Third Edition. N. Y. and Lond., McGraw-Hill Book Co., 1922. 315 pp., illus., diagrams, 9 x 6 in., cloth. $3.00.

A concise presentation of the physical properties of the common materials used in structures and machines, with brief descriptions of their manufacture and fabrication, is given by the author. The subject-matter is elementary in character and intended for use in technical schools, in connection with courses in the mechanics of materials. Bibliographies are appended to each chapter. This edition has been revised in the light of recent experimental data.

MATERIALS OF CONSTRUCTION.

By H. E. Pulver. (Engineering Education Series.) N. Y. and Lond., McGraw-Hill Book Co., 1922. 318 pp., illus., diagrams, 9 x 6 in., cloth. $3.00.

This book has been prepared primarily for correspondence study in the University of Wisconsin, but it will also, the author believes, prove useful for residence study in technical schools. The ordinary materials, plasters, cements, mortars, concrete, stone, brick, timber, and metals, are described, and their structural properties explained, in an elementary way.

NEW BUILDING ESTIMATORS' HANDBOOK.

By William Arthur. 1922 Edition. N. Y., U. P. C. Book Co., 1922. 1 002 pp., illus., tab., 7 x 5 in., fabrikoid. $6.00.

This well-known handbook has been revised, and reset in a smaller, although legible type, so that its size has not been increased. It is intended to assist architects, builders, contractors, and engineers in estimating the cost of new construction and repairs in all lines of building work, excavating, and municipal work.

ARCHITECTURAL DRAWING.

By Wooster Bard Field. N. Y. and Lond., McGraw-Hill Book Co., 1922. 161 pp., illus., 12 x 10 in., cloth. $4.00.

An effort has been made to provide those things which are of fundamental importance to the student in his initial study of the subject, together with a careful presentation of some of the important points that are usually left to be acquired during his office experience. The book should also be valuable to any one who deals with architectural work.

LITTLE BOOK ON WATER SUPPLY.

By William Garnett. Cambridge, University Press, 1922. 144 pp., illus., 9 x 6 in., cloth. $2.50. (Gift of the Macmillan Co., N. Y.)

A general account of the sources and mode of supply of water, with particular reference to the water supply of London, England. The text is intended for use in elementary schools or in conjunction with illustrated lectures in schools of hygiene.

HYDRAULICS.

By Horace W. King and C. O. Wisler. N. Y., John Wiley & Sons; Lond., Chapman & Hall, 1922. 237 pp., diagrams, 9 x 6 in., cloth. $2.75.

This book deals with the fundamental principles of hydraulics and their application in engineering practice. Although many formulas applicable to different types of problems are given, the aim has been to bring out clearly and logically the underlying principles that

form the basis of such formulas, rather than to emphasize the importance of the formulas themselves. The book is intended as a text for beginners and a reference book for engineers interested in the fundamental principles.

HYDRAULIC DIAGRAMS FOR THE DISCHARGE OF CONDUITS AND CANALS.

By Theodore Horton and C. H. Swan. Third Edition. N. Y. and Lond., McGraw-Hill Book Co., 1922. 53 pp., diagrams, 9 x 6 in., paper. $1.00.

This set of diagrams is intended for use in the study of those sections of conduits and canals which are commonly used in sewerage, water supply, water power, and drainage. The set includes conduits of ten different types of cross-section and canals of rectangular and trapezoidal cross-section. In this edition, one diagram previously used has been replaced by three new diagrams of more useful types, and the text has been revised and extended.

WAVE TRANSMISSION.

Proprietor and Patent Owner: Walter Haddon. Third Edition. Lond., 1922. 53 pp., illus., paper.

Wave transmission is the name chosen to designate the method for transmitting power invented in 1913 by George Constantinesco, in which the power is transmitted through waves or pulsations set up in an enclosed column of liquid. This pamphlet calls attention to the possibilities of the method as a substitute for others, particularly for hydraulic and compressed air transmission, and describes the wave generators and rock drills now on the market.

UNTERSUCHUNGEN UBER LAMINARE UND TURBULENTE STROMUNG.

Von L. Schiller. (Forschungsarbeiten auf dem Gebiete des Ingenieurwesens. Heft. 248.) Berlin, Julius Springer, 1922. 36 pp., diagrams, 10 x 7 in., paper. 30 marks.

The author gives herein the results of an exhaustive new investigation of laminar and turbulent flow in pipes, especially of the influence of various factors on the "critical" number. Certain variations from Poiseuille's law were detected, which had not been noticed by previous investigators, and an explanation is provided for them. In addition to its theoretical importance, this investigation should be of practical value, for it opens the way for the determination of viscosities by means of short tubes and makes possible the determination of absolute viscosity with the well-known Engler viscosimeter.

CURRENT CIVIL ENGINEERING LITERATURE

KEY TO ABBREVIATED REFERENCES TO PUBLICATIONS INDEXED*

Abbreviated References.	Publication.	Place.
Am. C. Inst	*American Concrete Institute, Proceedings* (Y.)	Detroit
A. I. E. E	*American Institute of Electrical Engineers, Journal* (M.)	New York
A. R. E. A	*American Railway Engineering Association, Proceedings* (Y.)	Chicago
A. S. T. M	*American Society for Testing Materials, Proceedings* (Y.)	Philadelphia
Am. Soc. C. E	*American Society of Civil Engineers, Proceedings* (M.)	New York
Am. Soc. Mun. Impvts.	*American Society for Municipal Improvements, Proceedings* (Y.)	New York
Am. W. W. Assoc	*American Waterworks Association, Journal* (Bi-M.)	Baltimore
Am. Wood Prs. Assoc.	*American Wood Preservers Association, Proceedings* (Y.)	Baltimore
Ann. P. et C	*Annales des Ponts et Chaussées* (Bi-M.)	Paris
Ann. T. P. Belg	*Annales des Travaux Publics de Belgique* (Bi-M.)	Brussels
Assoc. Ing. Gand	*Annales de l'Association des Ingénieurs sortis des Ecoles Spéciales de Gand* (Q.)	Ghent
Bost. Soc. C. E	*Boston Society of Civil Engineers, Journal* (M.)	Boston
Can. Engr	*Canadian Engineer* (W.)	Toronto
Cem. Eng	*Cement and Engineering News* (M.)	Chicago
Cornell C. E	*Cornell Civil Engineer* (M.)	Ithaca
Dock & Harbour	*Dock and Harbour Authority* (M.)	London
Eisenbau	*Der Eisenbau* (M.)	Leipzig
Eng.	*Engineering* (W.)	London
Eng. & Contr	*Engineering and Contracting* (W.)	Chicago
Eng. Inst. Can	*Engineering Institute of Canada, Journal* (M.)	Montreal
Eng. N. R	*Engineering News-Record* (W.)	New York
Engrs. Club, St. L	*Engineers Club, St. Louis, Journal* (Bi-M.)	St. Louis
Engrs. Soc. Pa	*Engineers' Society of Pennsylvnia, Journal* (M.)	Harrisburg
Engrs. Soc. W. Pa	*Engineers' Society of Western Pennsylvania, Journal* (M.)	Pittsburgh
Engr.	*Engineer* (W.)	London
Engrs. & Eng	*Engineers and Engineering, Engineers' Club of Philadelphia* (M.)	Philadelphia
Gen. Civ	*Le Génie Civil* (W.)	Paris
Gesund. Ing	*Gesundheits Ingenieur* (W.)	Munich
Inst. C. E	*Institution of Civil Engineers Minutes of Proceedings* (Q.)	London
Inst. Mun. & Co. Engrs.	*Institution of Municipal and County Engineers, Journal* (W)	London
Int. Ry. Assoc	*International Railway Association, Bulletin* (M.)	Brussels
Land. Arch	*Landscape Architecture* (M.)	Harrisburg
Mech. Eng	*Mechanical Engineering* (M.) *Journal of the American Society of Mechanical Engineers*	New York
Mil. Engr	*Military Engineer* (M.)	Washington
Min. & Metal	*Mining and Metallurgy* (M.) *American Institute of Mining Engineers*	New York
Mun. & Co. Eng	*Municipal and County Engineering* (M.)	Indianapolis
N. E. W. W. Assoc	*New England Water Works Association, Journal* (M.)	Boston
N. Y. R. R Club	*New York Railroad Club, Proceedings* (M)	Brooklyn
Oest. Ing. Arch. Ver	*Oesterreichischer Ingenieur und Architekten Verein, Zeitschrift* (W.)	Vienna
Power	*Power* (W.)	New York
Rev. Gen	*Revue Générale des Chemins de Fer* (M.)	Paris
Ry. Age	*Railway Age* (W.)	New York
Ry. Main. Engr	*Railway Maintenance Engineer* (M.)	Chicago
Ry. Rev	*Railway Review* (W.)	Chicago
Schw. Bauz	*Schweizerische Bauzeitung* (W.)	Zurich
Sci. Am	*Scientific American* (M.)	New York
Soc. Ing. Civ. Fr	*Société des Ingénieurs Civils de France, Mémoires et Comptes Rendus* (Q.)	Paris
Ver. deu. Ing	*Verein deutscher Ingenieure, Zeitschrift* (W.)	Berlin
West. Ry. Club	*Western Railway Club, Proceedings* (M.)	Chicago
West. Soc. Engrs	*Western Society of Engineers, Journal* (M.)	Chicago
Zeit. Bau	*Zeitschrift fur Bauwesen* (Q.)	Berlin
Z. d. Bauver	*Zentralblatt der Bauverwaltung* (Semi-Weekly)	Berlin

* Y = Yearly ; Q = Quarterly ; M = Monthly ; F = Fortnightly ; W = Weekly.

A. Applied Sciences

a. Processes of Calculation

2. Graphical and Nomographical

Règle Logarithmique, Système Rieger, pour le Calcul des Constructions en Beton Armé. Application au Calcul de la Flexion Composée.* (Rieger System Logarithmic Rule for Calculation of Reinforced Concrete Construction Application to the Calculation of Compound Deflections.) J. Rieger. Gen. Civ. Aug. 12, '22.

B. Applied Mechanics

a. Mechanics of Solids (Strength of Materials)

2. Elastic Solids

Die Drehungsfestigkeit von Stäben.* (Resistance of Bars to Twisting.) Constantin Weber. Ver. deu. Ing. Aug. 12, '22.

Zur Berechnung der Knickfestigkeit von Stäben mit mehreren Feldern.* (The Calculation of the Bending Resistance of Members with Several Bays.) Zimmerman. Z. d. Bauver. Aug. 12, '22.

4. Riveted Systems

Some Data on the Design of Steel Coal Bins.* R. Fleming Eng. N. R. Aug. 31, '22.

b. Hydraulics

3. Industrial Hydraulics

Turbines for the Great Falls Development of the Manitoba Power Company.* H. S. VanPatter. Eng. Inst. Can. Sept., '22.

Queenston-Chippawa Power Development.* H. G. Acres and others. Engrs. & Eng. Serial beginning Aug., '22.

Extension to the Hydro-Electric System of the City of Winnipeg.* E. V. Caton. Eng. Inst. Can. Sept., '22.

Wasserkraftanlagen mit stehenden Turbinen, Zahnrädergetrieben und Schirmdynamos.* (Water Power Plants with Vertical Turbines, Geared Transmission and Screened Dynamos.) E. Treiber. Ver. deu. Ing. July 22, '22.

Der Schrägaufzug für das Spullerseewerk.* (The Inclined Elevator for the Spullersee Plant.) Rob. Findeis. Oest. Ing. Arch. Ver. Aug. 4, '22.

Stand der Bauarbeiten beim Kraftwerk Partenstein. (Present Stage of the Construction Work of the Partenstein Power Station.) Oest. Ing. Arch. Ver. Aug. 4, '22.

Wirtschaftlichkeit und Ausbau der Wasserkraftanlagen in Oesterreich.* (Economy and Extension of the Austrian Water Power Plants.) L. Rosenbaum. Oest. Ing. Arch. Ver. Aug. 4, '22.

Wasserkraftanlagen mit gleichbleibender Kraftleistung.* (Water Power Plants with Constant Power Factor.) Janesch. Oest. Ing. Arch. Ver. Aug. 4, '22.

Finnlands Wasserkräfte.* (Water Powers of Finland.) Schw. Bauz. Aug. 5, '22.

Die projektierten Kraftwerke am Hinterrhein. (The Projected Power Plant on the Lower Rhine.) Schw. Bauz. Aug. 5, '22.

Der "Stossverlust" des Wassers beim Eintritt in Schaufelsysteme.* (The "Loss by Shock" of Water When Entering Blade Systems.) D. Thoma. Schw. Bauz. Aug. 19, '22.

c. Pneumatics

3. Industrial Pneumatics

Replacing Cables on a Two to One Traction Elevator Machine.* F. A. Annett. Power Sept. 5, '22.

Etude des Compresseurs d'Air.* (A Study of Air Compressors.) R. Pérot. Gen. Civ. Aug. 26, '22.

Untersuchungen an Luftpumpen für Kondensatoren.* (Investigations of Air Pumps for Condensers.. K. Hoefer. Ver deu. Ing. July 22, '22.

C. Materials of Construction and General Processes

a. Lime, Cement, Mortar, Concrete, Brick, Bitumen, Timber, etc.

Quality Control in Cement Manufacture. Richard K. Meade. (Paper read before Portland Cement Assoc.) Cem. Eng. Aug., '22; Can. Engr. Aug. 22, '22.

Brickwork from Building Stronger Than Laboratory Samples.* Rudolph P. Miller. Eng. N. R. Aug. 31, '22.

Tests of Concrete in Sea Water.* L. C. Wason. Am. Soc. C. E. Sept., '22.

Some Fallacies in Concrete Proportioning Theories. G. M. Williams. Eng. Inst. Can. Sept., '22.

The Chemistry of Portland Cement and Its Disintegration by Alkaline Ground Waters. T. Thorvaldson. Eng. Inst. Can. Sept., '22.

Effect of Age on the Strength of Concrete.* Duff A. Abrams. Eng. & Contr. Sept. 6, '22.

Testing Hollow Building Tile.* Wm. B. Newhall. Eng. N. R. Sept. 7, '22.

Das Wärmeschutzvermögen von Baustoffen nach dem Verfahren des staatlichen Materialprüfungsamts. (Ziegel und Kalksandstein).* (Heat Inlating Capacity of Building Material According to the Proceedings of the Government Material Testing Station. (Brick and Calcareous Sandstone.) Z. d. Bauver. Aug. 9, '22.

c. Preservation and Use of Materials. Painting, Waterproofing

Paint Protection for Wood.* Cornelius T. Myers. Mech. Eng. Aug., '22.

h. Foundations

Rock Borings for Highway Bridge Piers Made with Well Drilling Machine.* N. H. Meriwether. Eng. & Contr. Sept. 6, '22.

Modified U-Type of Abutment as Used in Wyoming.* J. F. Seiler. Eng. N. R. Sept. 14, '22.

Fundamente für Grosskraftmaschinen.* (Foundations for Large Prime Movers.) August Wolfsholz. Ver. deu. Ing. Aug. 12, '22.

j. Piles and Pile-Driving

Der Wolfsholzsche Presszementpfahl und seine Berechnung.* (The Wolfholz Molded Cement Pile and Its Calculation.) Joachim Schultze. Z. d. Bauver. Aug. 9, '22.

k. Tunnels and Tunneling-Shields

Caribou Tunnel Driven Under Heavy Inflow of Water.* W. D. Shannon. Eng. N. R. Aug. 31, '22.

l. Construction Machinery and Tools. Drainage

Wirtschaftlicher Betrieb der Baumaschinen.* (Economic Operation of Building Machinery.) Friedrich Merkel. Ver. deu. Ing. Serial beginning July 29, '22.

D. Highways

b. Load Resistance

Sur l'Usure des Routes par les Camions Montés sur Bandages Pleins et les Camions Munis de Pneumatiques.* (On the Wear of Roads by Trucks Mounted on Plain Tires and Trucks with Pneumatic Tires). M. Bonfils. Ann. P. et C. May–June, '22.

c. Construction

Comparison of Sub-Drainage by Deep Side Ditches and Tile Drains. C. H. Upham. (Paper read before Univ. of Michigan.) Can. Engr. Aug. 29, '22.

Strengthening Gravel Roads with Tar Surface Treatments at Elgin, Ill. Geo. E. Martin. Mun. & Co. Eng. Sept., '22.

Drainage Expert Discusses Highway as Compared with Agricultural Drainage.* Edgar A. Rossiter Mun. & Co. Eng. Sept., '22.

Construction of Reinforced Concrete Section of Lee Highway at Pulaski, Va. G. H. Derrick. Mun. & Co. Eng. Sept., '22.

Tar Surface Treatment of Gravel Roads in Maine. Paul D. Sargent. (Paper read before Univ. of Mich.) Mun. & Co. Eng. Sept., '22.

Asphaltic Cement Specifications. Gene Abson. Mun. & Co. Eng. Sept., '22.

Drainage for Roads in Prairie Regions. H. R. Mackenzie. (Paper read before Canadian Good Roads Assoc.) Eng. & Contr. Sept. 6, '22.

Road Construction in Prairie and Timbered Country. J. D. Robertson. (Paper read before Canadian Good Roads Assoc.) Eng. & Contr. Sept. 6, '22.

Importance of Plant Inspection in Bituminous Pavement Construction. Francis P. Smith. (From paper read before Univ. of Michigan.) Eng. & Contr. Sept. 6, '22.

How Iowa Levies Assessments for Surfacing Country Roads. F. W. Parrott. (From Iowa Eng. Soc. *Proceedings.*) Eng. & Contr. Sept. 6, '22.

Experiments in Improving Prairie Roads. K. A. Clark. (Paper read before Canadian Good Roads Assoc.) Eng. & Contr. Sept. 6, '22.

Slag-Concrete Roads—Their Construction and Wear. C. S. Hill. Eng. N. R. Sept. 14, '22.

"Inverted Penetration" Macadam Roads in Texas.* A. D. Stivers. Eng. N. R. Sept. 21, '22.

d. Maintenance

Highway Maintenance in Bureau County, Illinois. C. L. Melcher. (Paper read before Univ. of Ill.) Mun. & Co. Eng. Sept., '22.

Utilizing Existing Road Metal in New Construction.* G. F. Schlesinger. Eng. N. R. Sept. 14, '22.

Pavement Maintenance Experience in Wichita, Kansas.* P. L. Brockway. Eng. N. R. Sept. 7, '22.

e. Street Cleaning, Dust Prevention, Snow Removal

Snow Removal on Interurban Highways. C. J. Bennett. (From paper read before Univ. of Michigan.) Eng. & Contr. Sept. 6, '22.

f. Tree Planting

Selection, Arrangement and Planting of Road Side Trees.* C. F. Boehler. (From *Michigan Roads and Forests.*) Eng. & Contr. Sept. 6, '22.

g. Machinery and Tools

Concrete Hauled from Central Mixing Plant on State Highway Job in Walla Walla County, Wash.* Eugene R. Hoffman. Cem. Eng. Sept., '22.

Contractor Makes Ingenious Use of Available Equipment for Central Mixing Plant.* Cem. Eng. Sept., '22.

h. Vehicles. Automobiles

Highway Curves and Traffic Safety. H Eltinge Breed. (Comm. Report read before National Highway Assoc.) Can. Engr. Aug. 29, '22.

E. Bridges, Viaducts, and Arches

a. Timber Bridges and Viaducts

Bridge Inspection and Maintenance on Interurban Railway. J. H. Hyatt. (From *Electric Traction.*) Engr. & Contr. Sept. 20, '22.

d. Concrete and Reinforced Concrete Bridges

Special Form Work for Black Street Bridge, Hamilton, O.* (From *Miami Conservancy Bulletin.*) Eng. & Contr. Aug. 23, '22.

Special Trussed Falsework for Concrete Arch.* Merrill Butler. Eng. N. R. Sept. 21, '22.

La Repartition des Charges entre les Poutres dans les Ponts en Béton Armé.* (Distribution of Loads between the Girders in Reinforced Concrete Bridges.) Maximilien Thullie. Gen. Civ. Aug. 19, '22.

Der Neubau der Mersey-Brücke bei Warrington.* (The Rebuilding of the Mersey Bridge at Warrington.) Eger. Z. d. Bauver. Aug. 2, '22.

f. Suspension Bridges. Transfer Bridges

Building the Rondout Creek Highway Suspension Bridge.* W. E. Joyce and M. Bebarfald. Eng. N. R. Sept. 14, '22.

g. Swing, Bascule, Lift, Floating, Oscillating Bridges; Traveling Cranes

Riachuelo Transporter Bridge, Buenos Aires.* J. P. Risdon. Eng. Serial beginning Aug. 18, '22.

Bascule Highway Bridge, Port Dover, Ontario.* E. H. Darling. Aug. 29, '22.

Pont Levant sur le Canal du Midi, à Béziers (Hérault).* Lift Bridge Over the Midi Canal at Béziers (Hérault). Gen. Civ. July 29, '22.

Pont Basculant en Arc à deux Travées, à Caorle (Vénétie).* (Arched Bascule Bridge with Two Bays, at Caorle (Venice). Gen. Civ. Aug. 5, '22.

x. Miscellaneous

Artistic Design of Bridges. Charles Evan Fowler. (Paper read before Civil Engrs.' Club of Univ. of Toronto.) Eng. & Contr. Aug. 23, '22.

F. Inland Waters

a. Natural Waterways (General Articles)

The Outlets of the Danube.* Dock & Harbour. Sept., '22.

b. Canals (General Articles)

The Caledonian (Ship) Canal.* Eustace W. Porter. Dock & Harbour Sept., '22.

c. Regulation of Waterways. Volume of Discharge, Freshets, Floods, Soundings

Der Sturzregen im Emschergebiet am 31 Juli und 1 August, 1917.* (The Heavy Downpour in the Emscher Region on July 31st and August 1st, 1917.) Hummell. Z. d. Bauver. Aug. 2, '22.

Die Rhein-Regulierung Strassburg–Basel nach dem schweiz. Projekt vom September, 1921.* (Regulation of the Rhine, Strasbourg-Bâsle, According to the Swiss Plan of September, 1921.) Schw. Bauz. Serial beginning Aug. 12, '22.

g. Consolidation of Banks, Leakage, Maintenance of Channel, Dredging

The Meuse Lock on the Meuse-Waal Canal.* L. R. Wentholt. Engr. Serial beginning Sept. 8, '22.

Emergency Revetment on River Diversion Channel.* E. S. Blaine. Eng. N. R. Sept. 14, '22.

j. River and Lake Ports, Equipment

Large Hollow Concrete Blocks Form Dock Wall.* Cem. Eng. Sept., '22.

k. Utilization of Inland Waterways, Freight, Capacity

Der Oberrhein und die Zentralkommission für die Rheinschiffahrt.* (The Upper Rhine and the Central Commission for the Navigation of the Rhine.) Hoebel. Z. d. Bauver. Aug. 5, '22.

G. Maritime Works

a. Behavior of Movements of the Ocean. Winds. Waves. Tides. Currents

Veränderung der Hochwasserwellen durch natürliche oder künstliche Seeflächen.* (Modification of High Waves by Natural or Artificial Calming of the Sea.) Liczewski. Z. d. Bauver. Aug. 23, '22.

c. Vessels and Maritime Navigation. Lighthouses. Buoys. Various Signals

Ward and Operating Room Ventilation on Board Hospital Ship *Relief.** R. C. Holcomb. Engrs. & Eng. Sept., '22.

Le Nouveau Paquebot *Majestic* (Ex-*Bismarck*).* (The New Packet *Majestic* (ex-*Bismarck*). P. Calfas. Gen. Civ. July 29, '22.

f. Maritime Rivers and Canals. Bank Protection

Contribution a l'Etude Théorique des Fleuves a Marées et Application aux Rivières du Bassin de l'Escaut Maritime.* (Contribution to the Theoretical Study of River Tides, and an Application to the Basin of the Maritime Escaut.) L. Bonnet. Ann. T. P. Belg. Pt. 3, '22.

Sur la Théorie des Marées Fluviales et ses Applications.* (On the Theory of River Tides and Their Applications.) M. Ribière. Ann. P. et C. May–June, '22.

h. Wharves. Mooring Buoys. Harbor Equipment

Special Formwork Required in Setting Wharf Piers.* S. Kent. Eng. N. R. Aug. 31, '22.

i. Harbors (General Articles)

Two Ports of Puget Sound.* Taggart Ashton. Dock & Harbour Sept., '22.

Report Plans for Development of Shanghai Harbor.* Eng. N. R. Sept. 14, '22.

Construction Features of Harbor Works at Valparaiso. (From *Times Engineering Supplement.*) Eng. & Contr. Aug. 30, '22.

Les Travaux du Port de Tanger. Concours pour l'Adjudication des Traxaux d'Infrastructure.* (The Tanger Harbor Works. Competition for the Contract for the Masonry Work.) Gen. Civ. Aug. 19, '22.

Erweiterungen des Hafens von Rotterdam.* (Harbor Enlargement at Rotterdam.) Hetzel. Z. d. Bauver. Aug. 19, '22.

j. Dockyard Machinery and Shipyards. Drydocks

Die Erweiterung des Konig-Albert-Docks in London.* (Enlargement of the King Albert Docks at London.) Eger. Z. d. Bauver. Aug. 9, '22.

H. Railroads. Street and Interurban Railways. Automobiles. Aeronautics

a. Railroads

1. General Articles

Bolivian State Railway Being Built by Americans. Eng. N. R. Aug. 31, '22.

The Application of Engineering in Railroad Transportation. G. D. Brooke. West. Soc. Engrs. Sept., '22.

The Japanese Railways and Their Operating Problems.* H. K. Smith. Ry. Rev. Sept. 16, '22.

Note sur les Chemins de Fer de la Ruhr.* (Note on the Ruhr Railroads.) M. Andriot. Rev. Gen. Aug., '22.

Massgebende Grössen für die Anlage von steigenden Eisenbahnstrecken and für den Betrieb auf ihnen.* (Standard Dimensions for the Construction of Inclined Sections of Railroads and for Operating on Them.) L. Bräuler. Z. d. Bauver. Aug. 26, '22.

4. Track

Chicago Track Elevation Structures Being Strengthened.* Ry. Main. Engr. Sept., '22.

Burlington Creosotes Cypress Piles.* G. A. Haggander. Ry. Main. Engr. Sept., '22.

5. Signals and Safety Apparatus

Long Distance Operation of Railway Facing Points.* Engr. Sept. 1, '22.

The Union System of Automatic Train Control.* L. V. Lewis. (From paper read before Railway Club of Pittsburg.) Ry. Rev. Sept. 16, '22.

6. Rolling Stock (Locomotives, Cars)

Some Factors to be Considered in Freight Car Design.* H. W. Williams. Ry. Rev. Aug. 26, '22.

Mechanical Refrigeration of Railroad Cars.* W. M. Baxter. Mech. Eng. Sept., '22.

Automatic Box Car Unloaders for Grain.* F. Newell. Eng. Inst. Can. Sept., '22.

Michigan Central Mikado has Many Special Features.* Ry. Age Sept. 2, '22.

Locomotive Power.* E. C. Poultney. Engr. Sept. 8, '22.

Steel Diners for the Atchison, Topeka & Santa Fe.* Ry. Age Sept. 9, '22.

The Una-Flow Locomotive—Practical Possibly.* Ry. Rev. Sept. 9, '22.

Dynamometer Tests of the Locomotive Booster.* Ry. Age Sept. 16, '22.

Les Nouvelles Voitures Lits de la Compagnie Internationale des Wagons—Lits.* (The New Sleeping Cars of the Compagnie Internationale des Wagons-Lits.) M. Doassans. Rev. Gen. Aug., '22.

Locomotive Electriques des Chemins de Fer Fédéraux Suisses Type 1 B1—B1. Construites par les Ateliers de Sécheron.* (Electric Locomotives of the Swiss Federal Railways, Type 1 B1—B1, Built by the Secheron Works.) G. L. Meyfarth. Gen. Civ. Aug. 12, '22.

Chevalet de 100 Tonnes, Système Perbal, pour le Levage des Locomotives.* (Perbal System 100-Ton Trestle for Lifting Locomotives.) Gen. Civ. Aug. 12, '22.

Heizwagen mit Elektroden-Kessel für 15 000 Volt der Schweizer, Bundesbahnen.* (Heating Car with 15 000-Volt Electrode Boilers of the Swiss Federal Railroad.) F. Christen. Schw. Bauz. Aug. 5, '22.

Die Einphasen-Lokomotiven Typ 1-B-1 + B-1 der Ateliers de Sécheron, Genf, für die S. B. B.* (The Single-Phase Locomotives, Type 1-B-1 + B-1 of the Secheron Shops, Geneva, for the Swiss Federal Railroad.) G. L. Meyfarth. Schw. Bauz. Serial beginning Aug. 26, '22.

7. Use of Electricity

Survey of Electric Traction on American Railroads.* George Gibbs. Eng. N. R. Sept. 14, '22.

Steam Road Electrifications in the Argentine.* Lynn G. Riley. Ry. Age Aug. 26, '22.

Travaux et Projets d'Electrification de la Compagnie des Chemins de Fer du Midi.* (Electrification Works and Plans of the Compagnie des Chemins de Fer du Midi.) M. Fontaine. Ann. P. et C. May–June, '22.

L'Electrification des Chemins de Fer au Moyen de Courants Alternatifs de Fréquence Elevée.* (Railroad Electrification with High Frequency Alternating Currents.) Gen. Civ. Aug. 26, '22.

8. Stations. Engine Houses. Shops. Terminals

Twin Span Turntable Reduces Load on Center.* Ry. Age Aug. 26, '22.

Improvements to Moncton Yard and Engine Facilities.* S. B. Wass. Eng. Inst. Can. Sept., '22.

Factors Governing the Design of Passenger Terminals.* A. S. Baldwin. (Abstract read before Int. Ry. Congress in Rome.) Ry. Age Sept. 2, '22.

b. Special Railroads

9. Narrow Gauge. Light Railways

Standardization of Mine Tracks. J. D. Martin. Engrs. Soc. W. Pa. Apr., '22.

f. Aeronautics

3. Aeroplanes

The Helicopter and the Variable Pitch Propeller.* Mech. Eng. Sept., '22.

x. Miscellaneous

Les Nouveaux Hangars Métalliques pour Avions du Centre d'Aviation d'Orly (Seine).* (The New Metal Hangars for Airplanes at the Orley (Seine) Aviation Center.) F. Tayssier. Gen. Civ. Aug. 26, '22.

I. Municipal Water=Works. Agricultural Engineering. Irrigation

a. General Articles

The Mechanical Equipment of Waterworks. George R. Collinson. Inst. Mun. & Co. Engrs. Aug. 29, '22.

Comprehensive Program for Denver Water-Works System. (From Report of Eng. Board of Review.) Eng. N. R. Aug. 31, '22.

b. Hydrology. Water Resources

The Hetch Hetchy Water Supply of San Francisco.* M. M. O'Shaughnessy. Am. W. W. Assoc. Sept., '22.

Engineering Geology of the Catskill Water Supply.* Charles P. Berkey and James F. Sanborn. Am. Soc. C. E. Sept., '22.

c. Dams and Reservoirs

The Sukkur Barrage.* Engr. Aug. 25, '22.

Experiments With Models of the Gilboa Dam and Spillway.* R. W. Gausmann and C. M. Madden. Am. Soc. C. E. Sept., '22.

Tentative Plan for the Construction of a 780-Foot Rock-Fill Dam, on the Colorado River, at Lee Ferry, Arizona.* Discussion. C. R. F. Coutlee, H. B. Muckleston, Edwin H. Warner, F. A. Noetzli, Kirk Bryan, Arthur P. Davis, J. C. Stevens, J. H. Quinton, Ernest H. Baldwin, and C. S. Jarvis. Am. Soc. C. E. Sept., '22.

Closing 42 In. Outlet Pipes in Shoshone Dam Under 200 Feet of Water, with Wooden Balls. J. S. Longwell. (From *Reclamation Record.*) Eng. & Contr. Sept. 13, '22.

Plant and Program on the Hetch Hetchy Dam.* Eng. N. R. Sept. 21, '22.

Notes sur le Calcul des Barrages en Voute.* (Notes on the Calculation of Arched Dams.) G. Pigeaud. Gen. Civ. July 29, '22.

Barrages à Contreforts Triangulaires. (Dams with Triangular Buttresses.) G. Pigeaud. Gen. Civ. Aug. 5, '22.

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Beitrag zum Wasserschlossproblem.* (Contribution to the Water Reservoir Problem.) Stefan v. Finály. Oest. Ing. Arch. Ver. Aug. 4, '22.

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PAPERS AND DISCUSSIONS

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THE WATER POWER PROBLEM*

A SYMPOSIUM

* Presented at the meeting of the Society at San Francisco, Calif., on October 4th and 5th, 1922. The other papers presented at those meetings will be published in *Proceedings* for December, 1922.

THE COLORADO RIVER DEVELOPMENT

By Arthur P. Davis,* Past-President, Am. Soc. C. E.

The Colorado River and its tributaries constitute one of the greatest potential assets of the United States. Already serving more than 2 000 000 acres of farm land with irrigation water, it will eventually serve treble that area. It drains parts of seven States, and flows for more than 100 miles on Mexican soil. Before the building of railroads, it was navigated for more than 400 miles, and although now mainly abandoned by navigators, it is still navigable. This, and its interstate and international character, makes its problems peculiarly national.

Its great power possibilities are one of its most remarkable characteristics. Rising on the summit of the Rocky Mountains, at altitudes exceeding 14 000 ft., it flows rapidly through canyons abounding with rapids, to nearly sea level. It drains an area of about 244 000 sq. miles, including large areas of heavy snow fall, and its annual average discharge is about 18 000 000 acre-ft. This large volume of water, with its immense fall, indicates a total of 8 000 000 h. p., of which three-fourths is susceptible of development, whenever reasonable markets will justify it. In addition, its tributaries, widely distributed and already partly developed, have vast possibilities of power.

Its upper courses are mostly mountainous, and traverse a few valleys of moderate area. Its middle reaches are through plateaus scored by profound canyons, constituting, topographically, one of the roughest regions of the world. The lower stretches pass through hot dry valleys of alluvial silt, which are rich in all kinds of plant food and which have a growing season of twelve months. If properly regulated, the Colorado is ample to supply the much needed water for the irrigation of these semi-tropical valleys and to make them produce a wonderful abundance and sustain a dense and prosperous population. The discharge of the river is sometimes less than 5 000 cu. ft. per sec. and the mean flow is about 24 000 sec-ft. The peaks of its floods at Laguna Dam are at times more than 200 000 cu. ft. per sec. The low-water flow of the river is already appropriated for irrigation and cannot be greatly extended without storage.

The complete and efficient use of the river for power also requires its regulation by large storage works. The most important and the most urgent need of storage, however, is in the control of the destructive floods, which annually pour over the lower valleys. Every large alluvial valley has its problems of river control, but those of the Colorado are unique, on account of the peculiar topographic conditions on the lower river.

The Gulf of California formerly extended nearly 150 miles farther north than its present head, and the Colorado River emptied into its eastern margin about 100 miles south of the head, carrying annually into it more than 80 000 acre-ft. of silt. This deposition built a great alluvial delta which finally extended across the Gulf and cut off the connection of the northern end from the sea, converting it into an inland basin from which the water has been

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* Director, U. S. Reclamation Service, Washington, D. C.

mostly evaporated, leaving in its bottom the Salton Sea covering 300 sq. miles, with a surface nearly 250 ft. below sea level.

Like other similar streams, the river, laden with sediment, continually builds up its channel and immediate banks, and forms a ridge growing steadily higher, until the stream becomes so unstable that, in some great freshet, it abandons this high channel and follows some course on lower ground. In this manner, the stream swings back and forth over its delta which has been built to a height of 30 ft. above sea level, where it forms a barrier between the Salton Sea and the Gulf of California. The direct distance from this ridge to the Gulf is about 70 miles, and to the margin of the Salton Sea, the distance is a little more. As the inland sea is about 250 ft. below the Gulf, there is a constant tendency to flow northward, and if the river should break into this basin in flood time, it would rapidly erode a deep channel and would be exceedingly difficult to stop. Unless diverted, the river would fill the Salton Sea to sea level, or higher, and submerge the Imperial Valley, destroying all the towns, railroads, and farms, as there is no escape for the waters of the Salton Sea except by evaporation. This menace would be largely removed by the reduction of the floods of the Colorado River, and the control of its waters.

Some engineers have held that the sediment carried by the Colorado is so voluminous that the construction of storage reservoirs in the lower basin should not be attempted, but that such reservoirs should be built only in the upper basin, where the waters are comparatively clear. In the upper country, numerous good storage sites have been surveyed and found to be feasible. They intercept the major part of the water supply, but their use for the purposes of the lower basin is subject to serious objections.

If all the reservoirs found to be feasible above the canyon regions were constructed, more than one-half the drainage area would still be unregulated. Although this is the more arid part of the basin, it furnishes occasional serious floods, and the flood problem could not thus be solved. The Gila River alone, although draining only 21% of the basin, and contributing only 6% of the water, occasionally discharges floods the peak flows of which are more than those of the Colorado at Laguna Dam. These floods, although of short duration, and of relatively small total volume, are a menace and require separate storage. This is true also of any other large area not regulated by the reservoirs suggested. Another serious objection to so using the reservoirs of the upper basin, is that it would destroy their usefulness for local purposes in the upper States and thus virtually destroy the large resources dependent on them in their vicinity.

Fortunately, it has been disclosed that it is feasible to construct a dam in the granite gorge of Boulder Canyon, that will intercept practically all the drainage above the Gila and form a reservoir of any desired capacity, sufficient to regulate the entire flow of the river to any desired regimen of discharge. Such a reservoir would not only eliminate the flood menace of the river, but would also furnish the regulation and the head necessary to develop 600 000 firm h. p., and this same regulation would meet the requirements of irrigation in Arizona and California. The regulated flow would also supply two large power sites below it, still nearer the present markets. It is also fortunate

that the Boulder Canyon site is located so as to be within transmission distance of large available power markets in Arizona, California, Nevada, and Utah. It is within about 30 miles of a transcontinental railway, an important consideration as regards accessibility and cost.

The sediment delivered by the Lower Colorado River is estimated to be about 90 000 acre-ft. annually. This quantity can be stored by providing capacity additional to that required for other purposes; a capacity of 9 000 000 acre-ft. would store the silt for a century, and larger capacity can be provided if desired. Eventually, it will be necessary to provide regulation above, but this is so far in the future that the upper reservoirs will doubtless be built in ample time. Even if the Boulder Canyon Reservoir should entirely fill with sediment, the power head will be unimpaired. Thus, Nature has provided means for removing any conflict of interests between the upper and lower basins of the Colorado, and the way is open for an amicable agreement on a division of its waters, which are ample for all feasible uses in all the States concerned.

To accomplish such an agreement, a commission has been appointed, headed by Herbert Hoover, M. Am. Soc. C. E., representing the U. S. Government. A representative from each of the seven States directly interested is also included on this commission, which, it is hoped, will soon reach an agreement acceptable to all the States.

This will leave the upper States free to develop all their irrigation and power resources without the menace of antagonistic claims in the lower States. Feasible reservoir sites have been surveyed at Flaming Gorge on the Green River, at Juniper on the Yampa, and at Dewey and Gore Canyon on the Grand River. A site also exists at Ouray, on the Green River, which is capable of development to a capacity of more than 10 000 000 acre-ft., forming the largest reservoir in the upper basin, but it would occupy a valley that is desired for use as a railroad route between Denver and Salt Lake City and perhaps may be devoted to that use. Numerous reservoirs of less capacity on the smaller tributaries of the Colorado are available for local use in irrigation, with perhaps some power development.

About 1 526 000 acres of land are now irrigated in the upper basin and there is a possibility of bringing this development to more than 4 000 000 acres, or nearly three times the present area.

The lower basin, exclusive of the Gila Basin, now includes about 510 000 acres of irrigated lands, and this area can be increased to about 1 250 000 acres, exclusive of Mexico. Fortunately, the supply of water, if wisely regulated and applied, is ample to carry out all these projects and to develop more than 6 000 000 h. p., not only without injury to irrigation, but to the great benefit thereof. It is important that the facts be fully ascertained and used in formulating a comprehensive plan for the best use of the water, and that the development follows this plan.

PRESENT TENDENCIES OF WATER-POWER DEVELOPMENT IN NEW YORK STATE

By John P. Hogan,* M. Am. Soc. C. E.

The State of New York has an area of about 50 000 sq. miles, or approximately 2% of the area of Continental United States, excluding Alaska. It contains, however, one-tenth of the population and about one-eighth of the industries of the entire nation. Of an estimated central-station capacity of about 23 000 000 h. p. in the United States, more than 3 000 000 h. p., or about 13%, is in New York State and the production there of about 6 000 000 000 kw-hr. is about 15% of the total for the entire country. It is estimated that the installed capacity in prime movers in the State is about 5 000 000 h. p., of which 1 300 000 h. p. is in the form of water power and 1 200 000 h. p. is in individual steam plants, leaving the steam capacity in central stations and electric railways about 2 500 000 h. p. The total undeveloped water power in the State, including one-half of the potential energy of Niagara and one-half of that part of the St. Lawrence River bordering on New York State, is about 4 000 000 continuous h. p., divided as follows:

Niagara River..................................	2 000 000 h. p.
St. Lawrence River..........................	800 000 h. p.
Delaware River................................	150 000 h. p.
Interior streams..............................	1 050 000 h. p.

It is improbable that public opinion will permit complete utilization of the potential energy of Niagara, but competent authorities have estimated that at least 500 000 h. p. additional could be developed on the American side without detriment to the scenic effects of the Falls. Hugh L. Cooper, M. Am. Soc. C. E., considers the power on the St. Lawrence, either with or without a canal, as immediately available. Of the interior possibilities, the speaker estimates that about 800 000 continuous h. p. are susceptible of economic development, and that an installation of about 1 600 000 h. p. would be justified to permit operation on the market load factor. Therefore, sufficient undeveloped water power is available to permit replacing all the present steam power in central stations and electric railways, provided the water power was of sufficient flexibility to meet market conditions. The present annual coal consumption in New York State for manufacturing, lighting, and transportation purposes, exclusive of heating, is about 37 000 000 tons, of which, it is estimated, more than one-third could be saved by the development of water power. With the normal average price of coal at about $7 per ton, it is estimated that capital expenditures of about $1 000 000 000 for this purpose would be justified.

General

Two general classes of water powers exist in New York State, as follows:

First.—The great continuous powers on the Niagara and St. Lawrence Rivers.

Second.—The irregular powers on the interior streams.

* Cons. Engr., New York City.

The general characteristics of the present and proposed developments at Niagara and on the St. Lawrence River are too well known to the members of the Society to warrant their discussion in a paper of this character, except in as much as their operating characteristics effect the development of the irregular water powers and of steam auxiliaries.

This paper, therefore, will be devoted largely to a description of the present developments on the interior or intermittent streams and the tendencies in power developments on them.

The striking physical features of the State of New York are the great Adirondack Plateau in the northeastern corner, rising to a maximum height of 5 300 ft. above sea level, and the Western Plateau extending through the central part of the State, from the Hudson on the east to the western boundary, at an average elevation of about 1 000 ft. above sea level. The Adirondack Plateau drains to the west, north, and east, into the St. Lawrence Basin, and to the south into the Atlantic Ocean through the Hudson and its tributary, the Mohawk. The Western Plateau forms the divide between the St. Lawrence Basin on the north and the Mississippi (Allegheny), Susquehanna, and Delaware Basins on the south.

Fig. 1 is an isohyetal map of the State and Fig. 2 is a map with lines of equal run-off. These maps are subject to the errors due to the insufficient number of stations and lengths of records, but they give a general idea of precipitation and run-off conditions.

It will be noted that the maximum average annual precipitation is on the Adirondack Plateau (particularly in the southern and southwestern part) and along the valley of the Hudson, whereas, in general, the precipitation on the Western Plateau is low. Thus, the maximum annual precipitation on the Adirondacks is in excess of 60 in., and the average is about 44 in., as compared with an average of 39 in. for the entire State; whereas, on the Western Plateau, the average annual precipitation varies between 28 and 48 in., with an average for the entire area of about 35 in. The disparity between the run-off of the respective regions is still more striking, the average annual run-off for the Adirondack Plateau being about 26 in., whereas that for the Western Plateau is about 16 in. When distribution throughout the year, or variations through a series of years, is considered, the advantage of the Adirondack Plateau is still greater. It has greater lake area, more natural storage basins, and almost no cultivated ground, whereas the Western Plateau contains the most fertile land of the State and is in a high state of cultivation. Duration curves for an average year of the Hudson and Genesee Rivers, typical of the two areas, are compared on Fig. 3. The physical features of the Adirondack Plateau are also more favorable to water-power development, as there is an abrupt drop from the high plateau, generally in a succession of falls or steep rapids, whereas the descent from the Western Plateau, particularly on its southern side, is much more gradual.

The majority, therefore, of the interior water powers, both developed and potential, are on streams rising in the Adirondack Plateau.

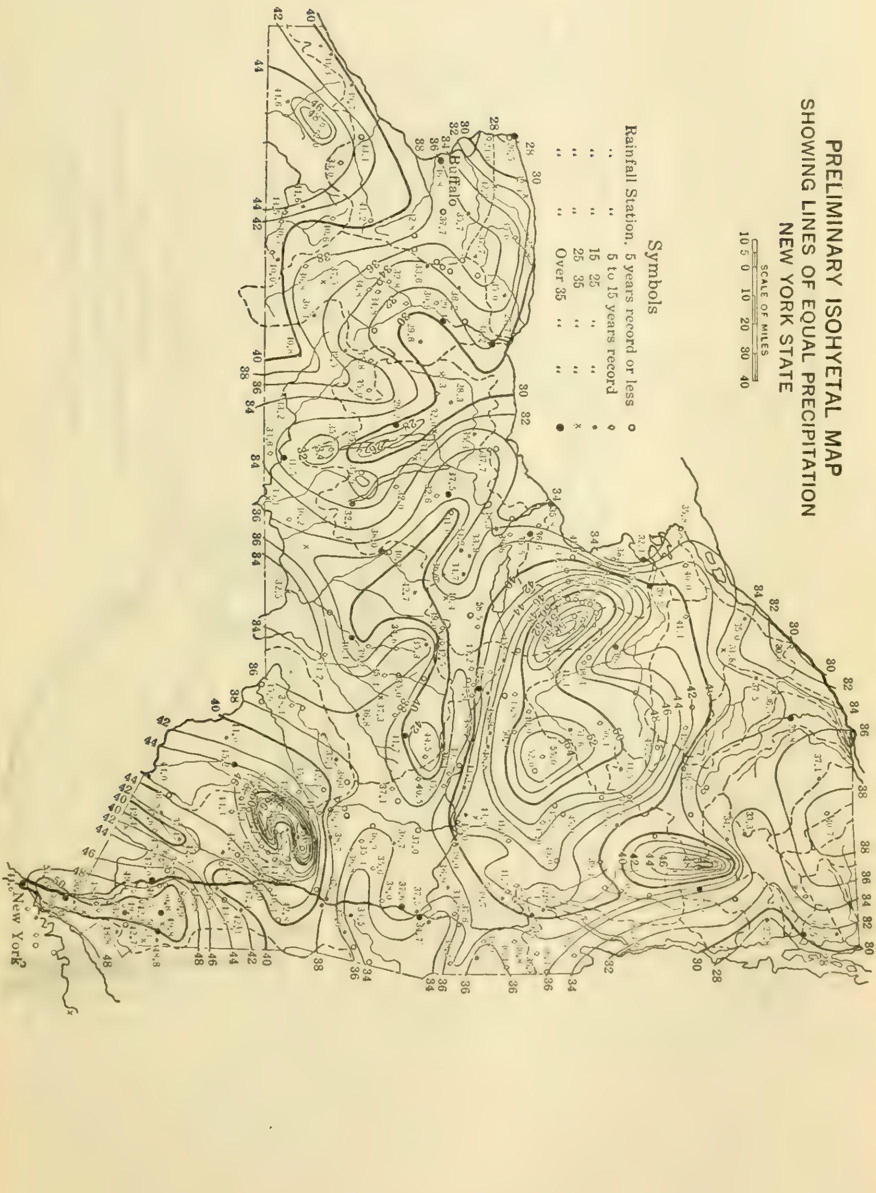
PRELIMINARY ISOHYETAL MAP
SHOWING LINES OF EQUAL PRECIPITATION
NEW YORK STATE
SCALE OF MILES
10 5 0 10 20 30 40
Symbols
Rainfall Station, 5 years record or less
" " 5 to 15 years record
" " 15 25 " "
" " 25 35 " "
" " Over 35 " "
Buffalo
New York

FIG. 1.

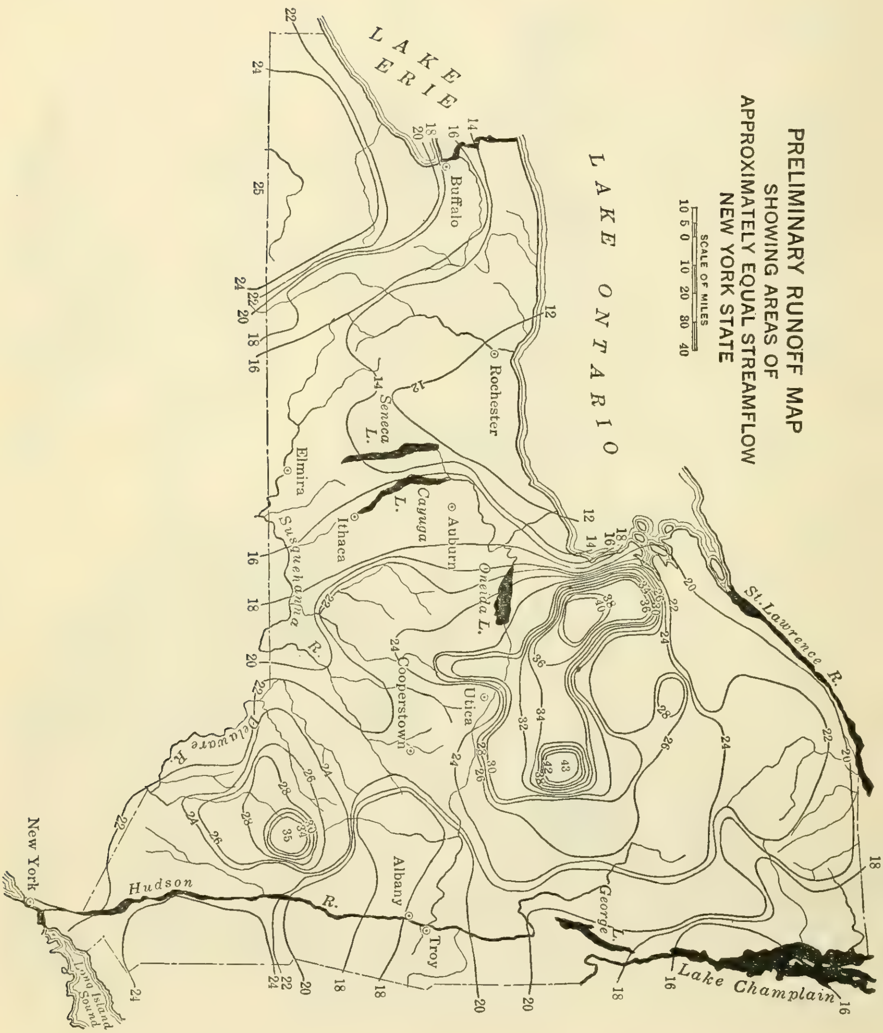
PRELIMINARY RUNOFF MAP
SHOWING AREAS OF
APPROXIMATELY EQUAL STREAMFLOW
NEW YORK STATE
SCALE OF MILES
10 5 0 10 20 30 40
LAKE ONTARIO
LAKE ERIE
Buffalo
Rochester
Seneca L.
Cayuga L.
Auburn
Ithaca
Elmira
Susquehanna R.
Oneida L.
Utica
Cooperstown
Delaware R.
St. Lawrence R.
George L.
Lake Champlain
Albany
Troy
Hudson R.
New York
Long Island Sound

FIG. 2.

Historical

The development of small mill powers in New York State dates back to the Eighteenth Century. The first large development in the State was started at Cohoes, on the Mohawk River, in 1833. This is the finest power site on the interior streams and has a total available fall of about 95 ft. and a drainage area of 3 600 sq. miles, giving an average annual run-off of about 6 000 cu. ft. per sec. The development was accomplished by means of three parallel canals on the hillside, with differences in elevation of about 20 ft. About 12 000 h. p. was developed by turbines or wheels operating mechanical drive, and a great textile industry grew up around this site. In 1917, a hydro-electric plant was substituted, which utilizes the full head and which will have an ultimate installation of 50 000 h. p., corresponding to the average annual run-off. The average power output is about three times that of the old installation.

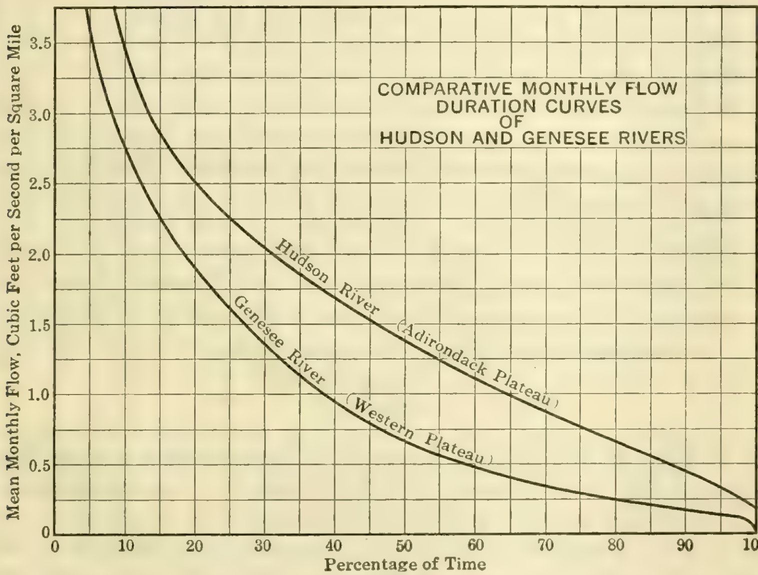

Fig. 3.

Other smaller mill powers were developed later, but the majority of the installations during the last century were for the purpose of pulp grinding and paper-making. The average installation was sufficient to use the water available for 60 to 70% of the time, and the intermittent flow was not of much consequence as the pulp wood could be stored, and the grinding (which consumed the larger part of the power) could be done at periods of high water. By the end of the Nineteenth Century, the water-power installations on the interior streams were in excess of 400 000 h. p.

The first large hydro-electric installation was at Spier Falls on the Hudson and was completed in 1903. The total head is 79 ft., the drainage area, 2 800 sq. miles, and the average annual run-off, about 5 200 cu. ft. per sec. The installation of eight horizontal wheels and generators is typical of the period,

but rather in excess of the average installation. It is capable of using the average annual run-off of 5 200 sec-ft. which is available for only 30% of the time in the average year (Fig. 4). It is believed that the size of the initial installation (considered excessive in those days) was dictated by financial reasons rather than sound economic policy. Considering the large pondage available at this plant (50 000 000 cu. ft. with a 4-ft. draft), this installation would be considered normal to-day.

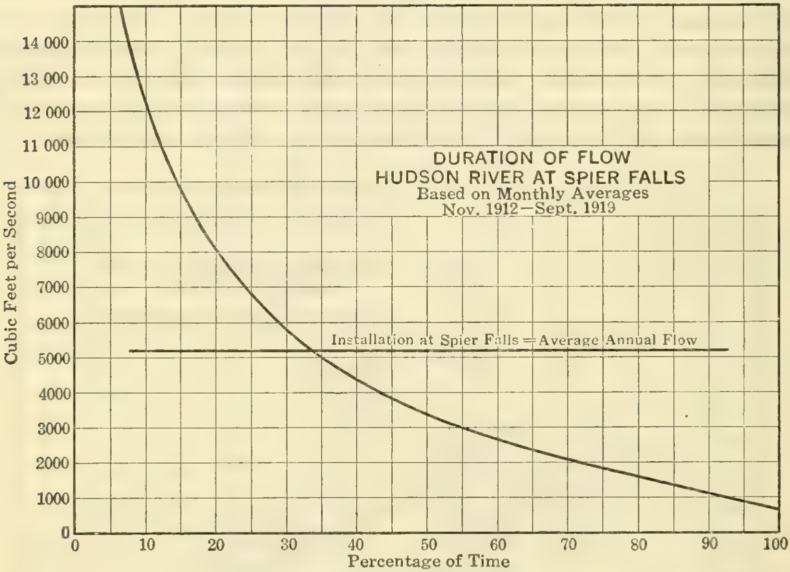

FIG. 4.

About 1903, the Indian Lake Reservoir, at the head-waters of the Hudson, having a capacity of 5 000 000 cu. ft. (115 000 acre-ft.), was constructed by an association of the power owners with the co-operation of the State. This reservoir and one on Salmon River, with a capacity of about 3 000 000 cu. ft., are the only storage reservoirs of any size, that have been constructed in New York State for power purposes. Small reservoirs have been built from time to time by private companies, and existing lakes and ponds have been drawn on during the dry months. The State also, from time to time, has constructed a number of large and small reservoirs to compensate for the diversion of waters for canal purposes. Power owners have benefited from such reservoirs, but private owners have done little or nothing to improve their powers by storage. One reason for this is the fact that, until recently, mechanical installations for paper-making were in the majority on interior streams, which installations have no great need for firm power or for storage, except in sufficient quantity to compensate for extreme low flows that might interfere with operations other than pulp grinding.

Since the construction of the Spier Falls Plant, nearly all new installations on interior streams have been hydro-electric, as well as certain of the additions

to existing mechanical plants. There has also been some substitution of hydro-electrical installation for mechanical plants so that, to-day, on the interior streams, there is about 400 000 h. p. in mechanical installations and about 500 000 h. p. in hydro-electric plants.

Present Situation with Regard to Water-Power Development

The development of more than 400 000 mechanical h. p. on the interior streams of New York State, prior to the introduction of electricity, and the enforced conformation of hydro-electric developments to existing developments have determined to a large extent the location and character of future installations. In the early installations, only the immediate use of the power was considered and advantage was taken of the most favorable locations without regard to ultimate possibilities. Even these sites were rarely developed to their ultimate limit. The average head utilized in the larger plants is less than 100 ft., and the maximum head at present is 270 ft. at Colton, on the Raquette, where 22 000 h. p. is developed. Opportunities existed at one time for heads of more than 600 ft. and installations of more than 10 000 h. p. through diversions from one water-shed to another. The formation of the Adirondack Plateau is peculiarly favorable for diversions on a large scale. The definitions between the various water-sheds at their common origin in the plateau are very slight, and the drainage from hundreds of square miles can be easily diverted from one stream to another. Lower down, the streams are often close together, with considerable differences of elevation at corresponding points. Owing to the large capital investment in existing plants on the various streams, most if not all of these opportunities are no longer economical, and a development of each stream in a succession of moderate steps is necessary.

Growth of the Power Market

The growth of the power market in New York State has been typical of that in the older industrial communities. First, there was a period in which small detached units were developed, followed by one in which gradual combination and expansion into local systems took place. The latter was followed by a highly competitive period resulting in absorption of some of the smaller plants and in consolidation and determination of territory. The combination of local companies into larger systems, which has been characteristic of some other regions, has not yet made much progress in this State. As a result, there is only one large distributing system in the State and only one transmission line of more than 66 000 volts, although a 110 000-volt line is now in process of construction by the Niagara, Lockport and Ontario Company, the distributing system previously mentioned. Even in Greater New York, three separate commercial companies and five different steam or rapid transit railways are producing power independently. In the last few years, a number of local interconnections have been made for the interchange of power, but, in general, there are a large number of strong local systems with the power generated either by steam or water within the district served. Therefore, even in the same territory, numerous differences in frequencies and in generating, transmitting, and distributing voltages have grown up between the

different systems and, even within systems, all stages of progress in the electrical art are sometimes illustrated. One small system actually uses all three frequencies as well as direct current.

Present Power Market

The power market of the State is varied in different localities, but may be divided into five groups.

First.—The region immediately surrounding Niagara Falls where the load is heavy industrial and electro-chemical, supplied entirely by water power, with an annual load factor of between 80 and 90 per cent.

Second.—Buffalo, and that part of the State west of Syracuse served by water power from Niagara, with a certain amount of steam auxiliary power for meeting peaks. The load is industrial and commercial, and the annual load factor is between 60 and 65 per cent.

Third.—The northern slopes of the Adirondacks, served entirely by water power, either from the interior streams or from the St. Lawrence. The load is largely industrial and the annual load factor is about 60 per cent.

Fourth.—The New York Metropolitan District, where the load is commercial, light industrial, and railway. All the electric power in this district is steam generated, and the combined load factor is about 40 per cent.

Fifth.—The remainder of the State, principally the valleys of the Hudson and Mohawk, served by intermittent water powers on the interior streams and a considerable amount of steam auxiliary. The load is mixed industrial and commercial, and the annual load factor is about 50 per cent.

To summarize: Outside New York City, the main source of electrical energy is water power, and the load is mainly industrial. Only in New York City does the lighting part of the commercial load play an important part.

The average annual load factor for the entire State is 42%, and complete interconnection would result in a load factor of about 50%, indicating a diversity of about 16%, as follows:

A = Sum of non-coincident peak......	1 708 500
B = Coincident peak	1 464 900
C = Diversity	16.6%

$$C = \frac{(A - B)}{B} \times 100$$

The characteristics of the ideal load that would be obtained by complete interconnection are shown on the duration curve, Fig. 5 and the peak day-load curve, Fig. 6. The theoretical saving in capacity that would result from interconnection would be about 250 000 kw., exclusive of the saving in reserve capacity which would inevitably follow. Other considerations, nevertheless, compel the conclusion that the economies in capital expenditure and operating expenses due to interconnection, in themselves, would not warrant the necessary expenditures for transmission. If, however, the further development and distribution of water powers should warrant the construction of trunk transmissions, great additional benefits would follow through the interconnections thus caused.

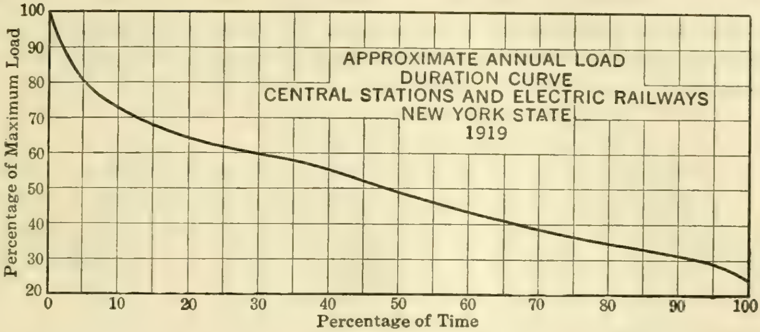
APPROXIMATE ANNUAL LOAD
DURATION CURVE
CENTRAL STATIONS AND ELECTRIC RAILWAYS
NEW YORK STATE
1919
Percentage of Maximum Load
100
90
80
70
60
50
40
30
20
0
10
20
30
40
50
60
70
80
90
100
Percentage of Time

FIG. 5.

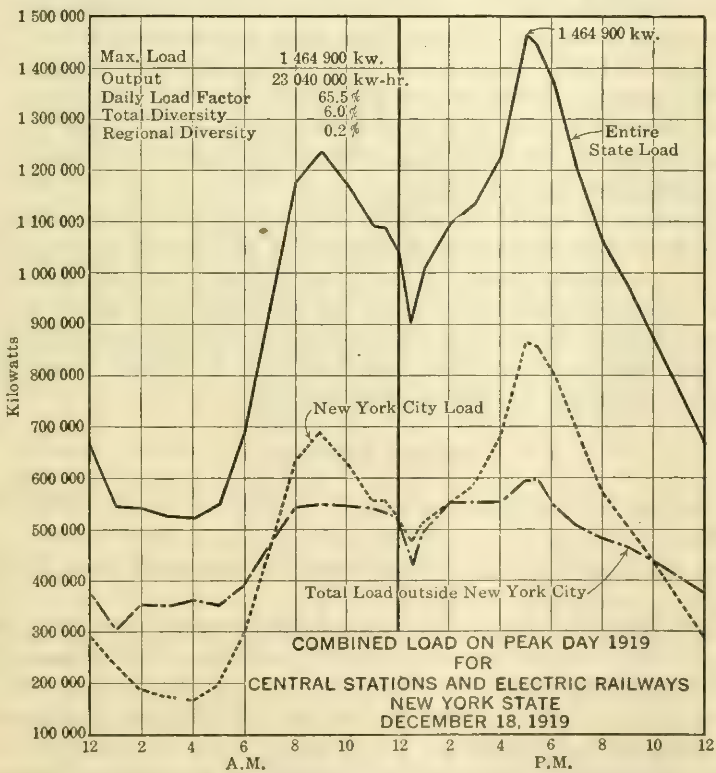
Max. Load 1 464 900 kw.
Output 23 040 000 kw-hr.
Daily Load Factor 65.5 %
Total Diversity 6.0 %
Regional Diversity 0.2 %
1 464 900 kw.
Entire State Load
New York City Load
Total Load outside New York City
COMBINED LOAD ON PEAK DAY 1919
FOR
CENTRAL STATIONS AND ELECTRIC RAILWAYS
NEW YORK STATE
DECEMBER 18, 1919
Kilowatts
1 500 000
1 400 000
1 300 000
1 200 000
1 100 000
1 000 000
900 000
800 000
700 000
600 000
500 000
400 000
300 000
200 000
100 000
12
2
4
6
8
10
12
2
4
6
8
10
12
A.M.
P.M.

FIG. 6.

Frequency

The chief obstacle to complete interconnection and interchange of power is the difference in frequency. In 1919, the total generating capacity in central stations and electric railways throughout the State was divided, as shown in Table 1.

TABLE 1.

Frequency.	Capacity, in kilowatts.	Percentage of whole.
25-cycle	1 464 600	67.2
40-cycle	116 400	5.3
60 cycle	516 000	23.6
Direct-current and miscellaneous	86 100	3.9
Total	2 183 100	100

A large part of the current generated as 25-cycle is utilized as direct current, whereas the direct current generated is utilized almost entirely in manufacturing processes. All the 40-cycle is concentrated in the Albany-Schenectady District. The 25-cycle is almost entirely concentrated in New York City and in the territory west of Syracuse served by the Niagara water powers. There is a large and growing 60-cycle capacity in the New York City Metropolitan District and throughout the remainder of the State, 60-cycle is in a rapidly growing ascendency.

The tendency is toward the gradual elimination of the 40-cycle frequency in favor of the 60-cycle and the restriction of the 25-cycle to territory now served. It is doubtful whether the 60-cycle frequency will ever gain a great foothold in the Niagara District, but the next ten years should witness a great reduction in the 40-cycle, the increase of the 60-cycle to at least a parity with the 25-cycle in New York City, and the virtual elimination of the 25-cycle frequency in other parts of the State.

Present Tendencies

The present tendencies in water-power development in the State of New York are:

First.—The substitution of hydro-electric for mechanical power in existing plants.

Second.—Plans for the provision of greatly increased amounts of storage.

Third.—The selective development and operation of water-power plants of varying characteristics.

Fourth.—Plans for the unified development of individual streams so as to utilize maximum possibilities.

Fifth.—Increased interconnection to permit of profitable interchange of power between plants of different characteristics.

Sixth.—Greater over-development for the purpose of meeting the market load factor and a decrease in the number of units.

Change from Mechanical to Hydro-Electric Power

The change from mechanical to hydro-electric power has been proceeding gradually and is almost completed in all industrial plants except those engaged in wood-working and paper-making. The principal use of power in paper-making (which utilizes more than three-quarters of the present mechanical power) is in pulp grinding, and there is practically no advantage in electrical installations, except in the possible disposal of surplus power. A number of factors are now tending against a continuance of the paper industry in New York State, among which may be mentioned the decreased supply of available timber and the increased cost of getting it to the mill, the increased value of hydro-electric power, due to the increased cost of producing power by steam, the growth of the electric power market in the immediate vicinity, the development of cheaper water power in Canada adjacent to plentiful supplies of pulp wood, and the operation of the present tariff. It may be safely predicted that the rate of change from mechanical to hydro-electric power will be greatly accelerated during the next decade. This power will seek an outlet in the growing public utility market and will tend to diminish the new hydro-electric construction.

Storage

Storage developments for power purposes in New York State, to date, have been insignificant. With about 900 000 h. p. installed on the interior streams, the total storage is only 20 400 000 000 cu. ft. (470 000 acre-ft.), or less than 1½% of the annual run-off. Of this, 14 300 000 000 cu. ft. has been provided by the State as compensation for canal diversion, leaving only 6 100 000 000 cu. ft. which has been provided by power companies for their own use. The Adirondack Plateau is a lake region with numerous large bodies of water. Unfortunately, the use of most of these lakes for regulation is greatly limited or prevented by the settlement along their shores of numerous summer colonies with expensive improvements. However, almost countless natural basins exist in thinly settled or wild localities, that can be economically improved. Within the Adirondack District, it has been estimated that there are 59 practicable reservoir sites with a total capacity of about 230 000 000 000 cu. ft. (5 300 000 acre-ft.), which is sufficient to store 32% of the average annual run-off in the District. It is physically possible, therefore, to control all the Adirondack streams to such an extent as to make them independent of any steam auxiliary, if this should prove desirable and economical. The limits of this paper do not permit discussion of the economic quantity of storage, but, at least, a certain proportion of these reservoirs are surprisingly cheap in view of the benefits that would be reaped.

There are many reasons why more storage has not been developed, but the chief reasons are as follows:

First (and Foremost).—The ownership, by the State, of 2 000 000 acres of land scattered through the Adirondack District. This constitutes the Forest Preserve and, by a provision of the Constitution, it can neither be sold nor used. There are only a few possible sites that do not contain at least one parcel of State land. It was not until 1916 that an amendment to the Con-

stitution, permitting the use of not more than 3% of these lands for storage purposes, was followed by the necessary legislation authorizing the organization of public corporations known as River Regulating Districts to take over such lands as are needed for the reservoirs. The intervention of the World War and the necessity of perfecting legislation have delayed action on any large scale, but one such district is now in successful operation and legal restrictions are now removed.

Second.—The co-operation between numerous independent owners of developed plants on each stream in the administration and expense of the storage reservoirs has been difficult to obtain in many instances.

Third.—A considerable proportion of the independent owners are paper-makers using mechanical drive. Most of their power is consumed in pulp grinding which need not be carried on continuously as the pulp wood is floated down on the spring floods and, in any case, must be stored. Grinding, therefore, can be done when there is sufficient water, and the only need of regulation is to prevent extreme periods of low water which may interfere with their other operations. They require, therefore, only a low degree of regulation as opposed to the high degree of regulation which is economical for the hydro-electric plant. However, as the average paper-making plant is installed for the flow available for 60 to 70% of the time and, for hydro-electric plants, the present economical installation is for the average flow or that available for 30% of the time, it is possible by adding an equal installation of hydro-electric apparatus at the paper plant to enable the combined installation to reap the full benefit of the high degree of regulation. The average small paper-maker is, however, loath to enter the hydro-electric field which he does not understand and in which he controls no market. The influence of the paper industry, therefore, has heretofore been against large amounts of storage and the gradual decline of this industry will accelerate the storage program.

Public and private investigations of the storage possibilities of the State have been made sufficient to establish the physical and financial features of the storage situations. As the way is now open from a legal point of view, and both public opinion and ideas within the utility industry have been crystallized, it would appear that a period of extensive storage development is now possible.

Selective Development and Operation of Water Powers

In New York State, there are two main classes of water powers to consider, that is, the continuous powers in the boundary streams and the intermittent powers on the interior streams.

The continuous powers were developed at first for continuous loads, such as those of the metallurgical and electro-chemical processes with which annual load factors of 80 and 90% are common. When the continuous powers were introduced to the general market with a prevailing load factor of 50 to 60%, it was found profitable to use these as far as possible on the base load and to obtain peak capacity from other sources. Thus, at Buffalo, only 20 miles from Niagara, is located the 100 000-kw., steam plant of the Buffalo General Electric Company, which operates in conjunction with continuous water power purchased from Niagara. The technical reasons for the construction and opera-

tion of this steam plant have never been clear in the public mind, and the charge is frequently made in the press that Buffalo has been deprived of her fair share of Niagara power. Attempts at denial or explanation are met by the statement, which is usually conclusive to the lay mind, that it has been necessary to erect a large steam plant in Buffalo. Nevertheless, if the continuous powers are to be utilized in the general market to the best advantage and with the greatest economy, it is certain that peak power must be supplied either from steam or from the intermittent interior water powers.

The interior water powers, owing to lack of storage, are at present dependent on large steam auxiliaries. This steam auxiliary makes possible a certain variety of operation, either carrying all the load by water in periods of high flow, or carrying base or peak loads by water or steam. When adequate storage regulation has been provided, it will be theoretically possible to operate without steam, although it is the speaker's opinion that a certain amount of steam power will always be utilized for regulation, flexibility, and occasional peaks. With complete storage regulation, it will be further possible for the interior water powers to be used as auxiliaries to the large continuous powers or to some large steam-power market, such as New York City. For working within a system by themselves, it will be possible to adapt the design of the different plants to the physical conditions. For example, a plant with good pondage, high head, and short pipe lines or penstocks may be greatly over-installed and used on the peak load, whereas plants of opposite characteristics may be operated continuously on the base load. It may be that certain streams can be devoted entirely to the production of peak power and others to that of base power.

An example of the harmonious development and operation of continuous water power, intermittent water powers with ample storage, and steam, is furnished by the system of the Niagara, Lockport and Ontario Company. The conditions in 1916 were, as follows:

Maximum 15-min. integrated peak..........	82 400 kw.
Total output for the year..................	427 045 000 kw-hr.
Average load factor for the year............	about 57%.
Capacity:	
Continuous hydro-electric power purchased from Niagara.........................	50 000 kw.
Installed capacity of hydro-electric power on Salmon River......................	32 000 "
Installed capacity of hydro-electric power at Minetto (Oswego), N. Y............	9 600 "
Installed capacity of steam electric power at Lyons, N. Y......................	29 500 "
Total capacity....................	121 100 kw.

All these plants are tied together by transmission lines nearly 200 miles long and are operated as a unit. If considered as independent plants designed to operate continuously on a normal load factor, the machine installations at

Salmon River and, to a smaller degree, at Minetto, are excessive. A normal installation for independent operation at Salmon River, considering the water available, would be not greater than 11 000 or 12 000 kw., as compared with the 32 000 kw. actually installed, and at Minetto not greater than 6 000 kw., as compared with the 9 600 kw. installed. This over-installation is the basis of the methods of operation.

Methods of Operation

The continuous water power, purchased at a flat rate, is operated on the base load at a high load factor.

The Minetto plant is operated generally during the day on the base load, with a high load factor while operating.

The peak load is taken by the Salmon River plant, aided by steam in seasons of low water, both operating on a low load factor.

Results

During 1916, the continuous water power had a load factor for the year of nearly 90%, and a consequent use of about 90% of the available water. The steam and water power operating on the peak had a load factor for the year of about 22 per cent. Owing to the great quantity of storage at the Salmon River plant (2 900 000 000 cu. ft.) and to over-installation permitting intermittent operation, almost 90% of the available water in this stream was used.

During 1919, only 31 000 000 kw-hr. of a total of 435 000 000 kw-hr., or 7% of the total power was furnished by steam. The result is, that with a system load factor of less than 60%, the load factor on water power while operating is nearly 90% and, consequently, nearly 90% of the available water is used. The extra expense chargeable to this method of operation is the cost of the additional machine installation at Salmon River as the transmission lines are necessary in any case as distributors. The fixed charges on this additional installation are only a fraction of the value of the increased output.

The future of water-power development in New York State lies in the provision of adequate storage for the interior streams and in the selective development and operation of the plants on these interior streams in harmony with the great continuous powers of the St. Lawrence and Niagara. Although the cost of development on the interior streams is uniformly greater, the ability to furnish peak power makes their output more valuable.

Unified Development of Individual Streams

These possibilities can be realized to their fullest extent only by stream regulation and the harmonious development and operation of a number of plants on a stream, or group of streams, in accordance with a well ordered plan, and by providing the necessary transmission ties, so that operation can be based on a community of interest and that development will no longer be governed by local considerations or the immediate market.

Considering the age of the water-power industry in the State, and the fact that it was well established on a number of the interior rivers prior to

the introduction of hydro-electric power, it is not surprising to find the greatest variety of ideas in the design of the different plants on a single stream. The mechanical and hydro-electric plants are interspersed, and the desirable methods of operation of the two types are dissimilar. Consequently, there is considerable interference at times. The ponding of water at night by the hydro-electric plants, if carried too far, tends to hamper continuity of operation in the mechanical plants, and as the installations of the latter are generally much smaller in proportion, may even cause considerable loss of power. Until recently, water-power legislation in the State was backward and the Courts usually relied on an interpretation of the common law by which every owner of riparian rights was entitled to the natural uninterrupted flow. Any harmonious scheme of development and operation, therefore, was dependent on unanimous private agreement which has never been accomplished. Interference between adjacent plants has generally been the subject of private agreement and mutual compromise, but on no stream of any size has a unified plan been devised and adopted for harmonizing the size of the installations and methods of operation of the various plants.

The organization of the River Regulating District based on a mutual understanding between all the power owners on a stream, has changed this situation, and the gradual conversion of the mechanical plants to hydro-electric power is removing the chief source of disagreement. The possibility of supplementing pondage by the release of water from the reservoirs during certain hours of the day, thus providing additional peak capacity, has drawn further attention to the necessity for unified operation. Plans have been prepared for the re-installation of a series of plants on one stream with a view to the operation of all of them for the maximum total output and the best operating conditions in the combination without regard to the individual plants. It may be stated, therefore, that there is a distinct tendency toward more harmonious development and operation.

Interconnection

For a long time, the method of growth of the power industry in strong local systems already described and the differences in frequency and voltage tended to minimize interconnection. Even between systems of the same nominal frequency there were often differences in actual frequency. The World War showed the importance of interconnection in permitting transfer of blocks of power and tended to overcome some of the differences. Interconnections and interchanges brought about by the war were often found to be profitable, owing to diversity of load or to the operating conditions surrounding certain water-power plants. For example, water-power plants with large pondage found it profitable to shut down at night during periods of low water and take surplus power from plants with small pondage, sometimes returning peak power to the latter by day. Local interconnection for such exchange has made great progress recently. Several trunk transmission lines of moderate length and voltage are now in course of construction or rehabilitation. It would seem that any general scheme of interconnection such as that

proposed by the Super-Power Survey is dependent on the development of water power on a large scale.

Over-Development and Decrease in Number of Units

On an unregulated stream, the present normal installation in hydro-electric plants is about sufficient to use the average flow. On the Adirondack streams, this will permit, during the average year, continuous operation for only 30% of the time; but continuous operation during a 10-hour day is assured for 65% of the time for the average year. This requires the pondage to be sufficient to conserve the night flow. Where no pondage is available, the installation is generally less.

As the minimum flow is increased by regulation, pondage requirements become somewhat greater, unless the reservoirs can be operated on an hourly schedule. On a fully regulated stream, the installation may be twice the minimum regulated flow available for 95% of the time, or even higher where ample pondage is available. This will permit of operation on an annual market-load factor of less than 50 per cent. The general tendency of the past few years has been toward greater installation, and this undoubtedly will be accentuated by regulation.

Number of Units

A time-honored rule among steam power plant designers is that an independent power plant should contain from five to eight units. In the early hydro-electric plants, of which Spier Falls is a type, eight units were used. Since that time, there has been an increase in the size of units and a consequent reduction in number. The principal limiting conditions in determining the number are the maximum economical size, the flexibility necessary for meeting load conditions, and the necessity for break-down reserve. With the growth of the market, the increase in the number of water-power plants in a system, and growing interconnection, the requirements for flexibility and break-down reserve have decreased. Sufficient flexibility for economic operation can usually be obtained with three units. The maximum number of units in plants of modern design is five and the minimum two. In general, it may be stated that present practice calls for three to five units, with a tendency toward the smaller number wherever the economic limit of size of unit will permit, and this will undoubtedly be accentuated by the tendency toward unified development and harmonious operation of all the plants on each stream.

Conclusion

In no part of the United States has conservation of natural resources through the development of water power been given more thorough and competent public and private study than in the State of New York. Nevertheless, during the past few years, development has lagged, and the additions which have been made, have been the result of individual initiative. Legal restrictions which have been largely responsible for the lack of accomplishment, have now been removed, and the speaker believes that the State of New York

is now on the eve of a comprehensive development of the natural resources on the interior streams. In order to obtain the greatest benefit, such a development must be based on a community of interest and thoroughly co-ordinated, in order that the maximum economic possibilities of each stream may be eventually realized. This means that there must be a general plan and that each individual step whether dictated by public or private initiative must fit into the general plan. Such a result can be realized only by the development of the spirit of co-operation.

THE OPERATION OF THE FEDERAL WATER POWER ACT

By O. C. Merrill,* M. Am. Soc. C. E.

Probably more water-power projects are now under construction than ever before in the United States, and the Pacific Coast, as usual, is leading in this work. One of the most important elements in this renewed activity is the Federal Water Power Act which was passed by Congress in 1920. Perhaps the time has been too short to permit of passing conclusive judgment either on the law or on its administration, but the fact that the applications filed with the Commission aggregate more than 20 000 000 h. p., and that the greater part of the projects now under way are being built under the provisions of the Act, should afford at least a tentative basis for appraising its value.

The early years of the operation of any statute are particularly important, because they are the period of its interpretation and of the establishment of precedents in its administration. For this reason, and also because this particular statute has so close a relation to the work of the engineer, it is desirable that all engineers should be familiar with its essential features and fundamental basis, with the manner in which it is operating, and with the results that are being accomplished.

Many members of the Society are familiar with the water-power situation as it existed before the present law was passed, and with the difficulties and uncertainties that surrounded any attempt to make use of the resources that came within the jurisdiction of the Government. The United States is the owner of the public lands, and these lands may be used only in such manner and for such purposes as Congress may direct. Through its power to regulate commerce, Congress has jurisdiction over all the navigable waters of the United States and may determine what structures may be erected in or over them and under what conditions. The manner in which international waters may be diverted and used is the subject of treaty between the nations concerned, and the sole power, in this country, of making and enforcing treaties is the Federal Government. These are the three fundamental bases on which rests the authority of Congress over water powers. Under this authority, it has control over the disposition of about 85% of the potential water powers of the United States. It is of great importance, therefore, that the legislation which Congress enacts shall be wisely conceived and intelligently administered.

It was the early policy of Congress to leave the regulation of navigable rivers, and, in a large measure, their improvement, to the several States and to acquiesce in the construction in such streams of whatever structures the State laws might authorize. A similar policy was first pursued with respect to the use of public lands for power purposes. This early policy was gradually modified through legislation which sought to preserve the public interest in the power resources under public control, but which failed to appreciate the conditions which were necessary if these resources were to be developed for public use. In fact, the Act of 1901 which applied to the public lands, and

* Executive Secy., Federal Power Comm., Washington, D. C.

the Act of 1906 as amended in 1910, which applied to navigable rivers, and which together constituted the legislation in effect when the Federal Water Power Act was passed, were adopted at too early a stage in the history of hydro-electric development to be suited to present-day conditions.

The Act of 1901 expressly limited the rights obtainable on the public lands to mere revocable licenses; and even these rights were jeopardized by the possibility that the lands to which they applied might be patented to others. Authority was granted in the form of permits issued under general regulations prescribed by the Executive Departments. The Act itself contained no expression of policy, and the regulations issued reflected the views of administrative officers and were subject to change at discretion. The Act of 1910 expressed the general conditions under which rights on navigable rivers could be secured. The grant itself required in each instance a special Act of Congress and was limited to fifty years. Plans were subject to approval by Federal authority, and the construction of locks or other navigation facilities might be required either at the time of original construction or at some indefinite time in the future. The failure of both Acts to make any provision for disposition of the properties or for extensions of the rights on termination, and the reserved right to revoke any permit or to alter or repeal any special act at any time without recourse in the grantee or liability in the United States, made financing almost impossible.

As a result of this unsatisfactory legislation only about 800 000 h. p., largely in extensions of existing projects, was constructed on the public lands and reservations under the Act of 1901, and about 500 000 h. p. on navigable streams under the provisions of special and general legislation. Of the latter amount, only 63 300 h. p. had been developed in 10 years under and following the Act of 1910. While six-sevenths of the nation's potential water-power resources were under Federal jurisdiction, scarcely more than one-seventh of existing developments had made use of sites under Government control. It became apparent, therefore, that any considerable utilization of these sites would require new legislation, and that such legislation must give consideration to the investment in the properties as well as to the rights of the public. The Federal Water Power Act is the result of the efforts to strike a balance between these two interests.

In place of the uncertain tenure and unknown requirements of previous legislation, an applicant for a power project under the Federal Water Power Act may secure a license for a period up to fifty years. The license is a contract between the Government and the licensee. It expresses all the conditions which the licensee must fulfill and, except for breach of conditions, cannot be altered during its term, either by the Executive or by Congress, without the consent of the licensee. If a licensee fails to commence construction, the license may be canceled by administrative action; but after construction has been started it can be cancelled only by judicial action, and only then if no other appropriate legal remedy is available. When the license period expires, the Government may take over the properties for its own use, may permit them to be taken by another, or may issue a new license to the original licensee.

If the properties are taken over before the term of the license expires, "just compensation" must be paid, as determined by the Courts in condemnation proceedings. If taken over at the termination of the license, the price is the "net investment," an amount which represents the original cost less so much of the then existing reserves as have been accumulated out of earnings, in addition to a fair return. If the properties are not taken over by the Government or by another, the licensee is entitled to a new license on such terms as will be reasonable in view of conditions then existing. In so far, therefore, as action of the Federal Government is concerned, full recognition is given to every dollar of honest investment, but to no more.

A licensee under the Act, however, has obligations as well as rights, but these obligations have for their purpose the creation of conditions under which electric energy can be produced and sold at the least amount consistent with the protection of the investment and a reasonable return. The Act requires that works be designed with due regard to safety and efficiency and to the fullest practicable utilization of the water power available, that they be maintained in full operating efficiency, and that all necessary renewals and replacements be made. It requires that reserves be established out of earnings, in order that assets or credits may be available from which replacements can be made and by which the investment may be kept intact. The Act also requires the maintenance of such a system of accounts as may be prescribed by the Commission, in order that information may be had with respect to investment and earnings, and that when the license expires records may be available adequate for determining the terms of settlement, should the properties be taken away, or the terms of extension, should the license be renewed.

The Act provides for permanent public ownership and control of power sites on public lands and of power privileges in navigable and international streams, and for their development by private capital under full public supervision and regulation. It prohibits capitalization for purposes of rate-making or of public purchase of rights, franchises, lands, or other properties, in excess of their legitimate cost. It requires that compensation be made for rights granted and for the use of lands or other properties of the United States; and it provides that a part of any earnings in excess of a specified reasonable rate of return shall be used in retirement of the investment in the properties.

That these provisions of the Act are adequate to protect every legitimate public interest is evident from their mere recital. That the Act also affords conditions under which capital may be secured for development purposes is evidenced by the results accomplished in the $2\frac{1}{4}$ years in which the Act has been in effect. In this time, 348 applications for permits or licenses, involving an aggregate estimated installation in excess of 20 000 000 h. p., have been filed with the Commission. This amount is more than twice the existing water-power installation of the United States. It exceeds the combined potential water-power resources of Norway, Sweden, Finland, and the Arctic and Baltic drainages of Russia—the chief water-power region of Europe. It is nearly twice the combined resources of France and Italy. It is more than six times the aggregate of all applications for power sites under Federal control in the preceding 20 years. To October 1st, 1922, the Commission had author-

ized 64 preliminary permits and 64 licenses, of which 25 were for transmission lines. The 60 permits now outstanding involve an estimated installation of 2 540 000 h. p., and the 39 licenses for power projects, 2 040 000 h. p., or a total of 4 580 000 h. p. Of the projects covered by the 39 licenses, 15, involving an estimated installation when completed of 1 880 000 h. p. and investments of not less than $250 000 000, are either completed or under construction. This is one and one-half times as much as was constructed under Federal authorization in the 20 years preceding the passage of the Federal Water Power Act. As a practical result of the present law, probably more water power is now under construction than at any previous period.

The problems in the administration of the Act are many and varied. Duties have been placed on the Commission not hitherto exercised by the Executive Departments. Policies and practices must be developed to meet the new situation created by the passage of the Act. The Act itself has required interpretation, and decisions have been rendered respecting the relations of the Commission to other agencies, State and Federal, and the bearing of State and Federal laws and international treaties on the work of the Commission. No attempt will be made to discuss these matters, nor the various duties of the Commission, in any detail, as time would not permit. The speaker does wish, however, to consider two questions relating to the Commission's jurisdiction, which are of major importance, for on its policies in this respect will depend in no small degree the successful administration of the Act. Whether any particular project must secure a license, and what is the line of demarcation between the regulatory—or supervisory—powers of the Commission and those of the several States, are the two chief jurisdictional questions. Neither is completely answered by the Act itself, and neither could be, without depriving the Commission of that discretionary power necessary for dealing intelligently with the particular facts of individual cases.

When power projects involve lands or other property of the United States, the jurisdiction of the Commission admits of no doubt. Ownership is a question of fact, and when the fact is established, the authority of the Commission is clear and exclusive. Outside the public lands and reservations, the jurisdiction of the Commission involves two classes of streams: First, those streams which are defined in the act as "navigable waters," over which the Commission has direct jurisdiction, and in which development cannot lawfully be made without its prior approval; and, second, those non-navigable tributaries of navigable waters in which power development, by altering the natural flow, would affect the navigable capacity of the navigable waters. The second class comes under the jurisdiction of the Commission only when declarations of intention to construct dams within such streams are filed with the Commission.

The construction of power projects on streams of the first class, that is "navigable waters," without first securing a license under the Federal Water Power Act, would be subject to the penalties prescribed by that Act and by the Act of March 3d, 1899, which prohibits without prior approval "the creation of any obstruction * * * to the navigable capacity of any of the waters of the United States."

The Federal Water Power Act defines navigable waters as:

"* * * those parts of streams or other bodies of water over which Congress has jurisdiction under its authority to regulate commerce with foreign nations and among the several States, and which either in their natural or improved condition notwithstanding interruptions between the navigable parts of such streams or waters by falls, shallows, or rapids compelling land carriage, are used or suitable for use for the transportation of persons or property in interstate or foreign commerce, including therein all such interrupting falls, shallows, or rapids; together with such other parts of streams as shall have been authorized by Congress for improvement by the United States or shall have been recommended to Congress for such improvement after investigation under its authority."

Whether a stream has been recommended for improvement, or improvement has been authorized or actually made, is a simple question of fact. Whether a stream is used in the transportation of persons or property in interstate or foreign commerce is also a question of fact which may be determined on investigation; but whether, if so, the amount or character of such commerce is sufficient to warrant the assertion of jurisdiction by the Commission is a matter for decision in the individual case. Similarly, whether a stream which is not now used in interstate or foreign commerce, is suitable for such use, is a matter of judgment, and decision must rest on the character of the stream and on the probability of the future development of commerce.

The Act provides a procedure whereby any one proposing to build a dam in any stream of doubtful status may make declaration of his intention and have the matter conclusively determined by the Commission. There has been criticism, particularly in the New England States, that the definition contained in the Act is not clear and that the Act should be modified or the definition interpreted by the Commission so that the limit of navigability on any stream may be determined with such exactness that no one need ever be in doubt or need ever apply to the Commission for its determination.

The question of navigability is not one of mathematical formulas; and there is no more probability that it can be removed from the domain of individual judgment, than that laws in general can be drawn with such precision that the services of the Courts can be dispensed with in their interpretation. The decisions of the Commission in the individual cases presented to it will establish precedents that will gradually clear the situation. Three recent cases, on interstate streams, the Saco River, running from New Hampshire into Maine, the Connecticut, a boundary between New Hampshire and Vermont, and the Menominee, a boundary between Wisconsin and Michigan, are indicative of the policy the Commission is pursuing. The first two are actually carrying property in interstate commerce in considerable quantities in the form of logs and pulpwood, and the third is suitable for such use. All three are, therefore, technically navigable; but due to the fact that, in each instance, the laws of the State afford full protection to such commerce, and that the proposed dams would not obstruct it, the Commission made formal finding that the streams were not "navigable waters" within the definition of the Act, that the proposed dams would not affect the interests of interstate commerce, and that, therefore, no Federal license was required for their con-

struction. The Commission does not propose to extend its jurisdiction in this respect beyond the point where some substantial interest of interstate or foreign commerce is involved.

The Commission has certain purely administrative duties. It has others which are more or less regulatory in their nature. It must be assured, for example, that the projects which it licenses, are adequately maintained and efficiently operated; that a system of accounting is established; that periodical reports are made; that adequate depreciation reserves are created and maintained; and that under certain circumstances amortization reserves are set aside. In the absence of State authority, it may regulate the rates and services and the issuance of the securities of its licensees. In some respects, its authority is exclusive; in other respects, its authority is concurrent with similar authority of the several States, and the question at once arises where should the jurisdiction of the one end and of the other begin, for it is manifestly desirable that State and Federal agencies work in harmony and that each assume responsibility for those duties which, at any particular time, it is in the best position to perform.

The fundamental difference between the regulatory power which should be exercised by State agencies and that which should be exercised by the Federal Commission is in the basis on which each rests. The former is chiefly, if not exclusively, an exercise of the police power; the latter is largely the enforcement of a contract obligation. The primary responsibilities of the Federal Power Commission, therefore, relate to the general plan of the project and its relation to other projects and other uses; to the design, maintenance, and replacement of the works; and to the determination, or to the methods of determination, of the items which make up the net investment. These are matters of supervision rather than regulation, and are to be exercised occasionally rather than constantly. The primary responsibilities of the State, on the other hand, are regulatory in nature, require continuous exercise, and have reference chiefly to the relations between the licensee and the general public. They are concerned with the quality and extent of service rendered, with the rates to be charged therefor, and, as incidental thereto, with the character and amount of securities to be issued, and with the system of accounting to be established and maintained.

In recognition of this situation, it has been the intention in preparing regulations and in adopting procedure for the administration of the Act to limit Federal supervision and control to those matters for which the Commission must itself assume responsibility under the provisions of the Act; and even within this limit to leave as far as practicable initial responsibility to the States in those matters where the latter also have jurisdiction under their own statutes, reserving to the Commission the right to take initial action in any matters not covered by State statutes, and reserving also the right to add to State requirements if such requirements do not meet those specifically imposed by the Federal statute. The Commission is not desirous of extending its own jurisdiction, but believes that the best results can be secured through co-operative action with the agencies of the States.

In addition to the duties already mentioned, the Commission is required to investigate all projects applied for, in order to determine whether the structures are safe and properly designed, and whether full utilization will be made of the resources of the stream; it must investigate and pass on applications for restorations to entry of lands in power-site reserves; and it is required to make valuations of all properties licensed under the Act and constructed prior to the issuance of a license. It is manifest that the duties placed on the Commission with respect to water powers are many times greater than have ever been assumed before by any of the agencies of the Government; and yet to perform these duties, the Commission—so the Comptroller General has ruled—may have no personnel of its own, other than its Executive Secretary and Engineer Officer, but is obliged to borrow for its work such personnel as the Departments can spare and are willing to loan. Although there is no disposition to criticize the Comptroller's decision from a legal standpoint, it is not believed that it represents what Congress intended. The Commission, nevertheless, has been operating two years under these unsatisfactory conditions with a detail of 8 engineers, 2 attorneys, 2 accountants, and 18 clerks—a force utterly inadequate to perform the duties placed on it by the Act. The Commission has no field force of its own, loaned or otherwise, but must depend for examinations and reports and for the conduct of field hearings on the field officers of the Departments—men who are primarily responsible for their own departmental duties. It was given originally an appropriation of $100 000, and this amount was repeated for 1922. For 1923, it has only the unexpended balance of its first year's appropriation; and yet, from lack of personnel, it will not be able to use even this.

Under the circumstances, the Commission has been obliged to delay action on many important projects, and it has been forced to omit altogether the performance of important duties required by the Act. This is particularly true of valuations, of which cases involving approximately $100 000 000 are now awaiting action. The Commission has been unable to secure the detail of any personnel with adequate experience in valuation work and, therefore, has been obliged either to suspend issuance of licenses where valuations are involved or to provide for valuations in the future. It has taken the latter course, in order that much needed power development might proceed. Such a course, however, is almost certain to result in prolonged litigation and in expenses many times greater than would have been required had the Commission been given the means for carrying out this requirement of the law in the beginning.

By confining its activities primarily to applications for power projects, declarations of intention, and requests for restoration to entry, the Commission has been able to take final action on more than one-half the applications for permits and licenses, or a total of 197. Of the remaining 151, 20 are not sufficiently complete for action to be taken, and action on 27 others must await prior action of other agencies. The Commission has also rendered decisions on 36 declarations of intention, passed on restorations to entry in 200 cases, and made withdrawals of 1 250 000 acres of public lands in connection with applications for power projects. Although the two years' record is reasonably satisfactory, in view of the serious handicap under which it

is working, the Commission, nevertheless, should promptly be placed in a position where it would be possible for it fully to carry out the purposes plainly expressed in the law. The present situation necessarily results in an administration of the law, which is insufficiently co-ordinated and only partly effective. The chief purpose of the creation of the Commission was to secure a common policy and a single executive agency in water-power administration. This purpose has not been accomplished. Other agencies are still continuing their independent activities, and these activities are not controlled by a common plan and are not subject to a common direction. This defect will not be cured, and the Commission will not be able to perform in full the duties placed on it, until the Act is amended so that it may employ its own personnel. It is important that this action be taken at an early date. Having waited ten long years for a legislative pronouncement of a Government policy respecting the utilization of the huge water power resources of the United States, it should not be necessary to wait another long period of years before means are provided for the execution of that policy.

There is one other matter to which attention should be directed. There are movements on foot in several quarters to secure for certain sites or streams special legislation, which, if approved, would constitute a partial repeal of the Federal Water Power Act, and eventually would result in the progressive disintegration of the present National water power policy. If these proposals that rights or authorities be granted independently of the present law, are examined, it will be found that some or all of the essential features of the Act, particularly those that protect the public interest, have been omitted, even when provisions in direct conflict have not been substituted. Furthermore, the granting of special privileges to favored interests would clearly discriminate against those who in the faith that Congress had at last fixed its policy, are investing hundreds of millions of dollars under the obligations of the Act. The results already accomplished afford convincing evidence that grants of special privileges are not necessary in order to secure the development of all the electric energy that the market can absorb.

The law, of course, is not perfect. Many changes could be suggested, even if every one did not agree on what changes would be desirable. However, after many years, a law has been enacted under which development is rapidly proceeding. It would be folly under such circumstances to permit the law, or the policy which it expresses, to be essentially modified, except after fair trial and convincing evidence of the desirability of change. All those interested should rather unite in working out, within the broad limits of discretion which the Act permits, practices and policies that will hasten the use, under proper conditions, of the vast water-power resources of the United States.

HIGH-VOLTAGE POWER TRANSMISSION

By F. W. Peek,* Jr., Esq.

The subject of power transmission will be discussed for the purpose of bringing out limitations imposed by engineering difficulties resulting from the use of high voltages. This will involve a consideration of insulation, regulation, and reliability of operation.

Assuming equal reliability, the transmission voltage must be decided purely from the economic standpoint. Although it is intended to confine this paper principally to the technical problems involved, it will be necessary to consider, to some extent, the economic side. In general, the economical use of the higher voltages will require large concentrated sources of power with a large demand at some distant point; and it seems that in the end this will be the real criterion of the voltage limit and not engineering difficulties of insulation.

During the last twenty years, transmission voltages have increased at the rate of 8 000 volts per year. Engineering has more than kept up with economic demands, and it is not likely that such demands will increase indefinitely at this rate.

In all engineering work, it is necessary to conduct research well in advance of the art. As early as 1910, in anticipation of 220 000-volt transmission, a section of a 250 000-volt line was constructed in Schenectady, N. Y. At that time, the laws of corona, shielding of insulators, etc., were investigated.

After more than ten years, 220 000-volt transmission is about to be realized in practice on two large systems in California. Transmission voltages of more than 1 000 000 volts were investigated in Pittsfield, Mass., during September, 1921, and the investigation has since been carried to 1 500 000 volts. Such high voltages may never be necessary for power transmission, but a study of characteristics over a wide range is of great practical importance.

In order to make the discussion definite and practical, the characteristics of the highest voltage systems at present will be considered first and, later, those of a 1 000 000-volt system will be discussed. It is hoped that a perspective of the whole field will be obtained by considering the two extremes.

As stated previously, high-voltage lines must be able to deliver a large amount of power. It is well, perhaps, to start with a definite idea of what this means. Roughly, 220 000 volts will be required when the power transmitted is 50 000 to 100 000 kw. or more per circuit and the distance is 150 to 300 miles or more. At 1 000 000 volts, economical transmission would probably required at least 2 000 000 kw. per circuit and distances of 1 000 miles or more. The necessity of transmitting a large amount of power per alternating-current circuit at 1 000 000 volts is evinced, for example, by the fact that about 7 000 kv-a. per mile is required to charge a line at 60 cycles. These figures are given only as approximations, the exact figures for any particular case depending on many conditions. However, they do make apparent the

* Cons. Engr., Gen. Elec. Co., Pittsfield, Mass.

enormous power and size of electrical units that are necessary for economical transmission at very high voltages, as well as the energy that must be safely controlled during a short circuit.

It is generally desirable to operate each line as a unit with regard to generator and transformers, and this requires quite large units for 220 000-volt transmission. At this voltage, when the power requirement is from 50 000 to 100 000 kw., the space limitation on the railroads has almost been reached for built-up units. At higher voltages, transportation of built-up transformers would not be possible, and it would also be difficult, at present, to obtain material sufficiently large for such transformers.

The apparatus discussed in this paper is the transformer, the switch, the lightning arrester, the transmission-line conductors, the line insulator, and the synchronous condenser. This apparatus will be discussed in order, with regard to a 220 000-volt line.

Transformers.—The transformer which is the connecting link between the high and the low-voltage systems, has undergone some remarkable changes during the last ten years. As the kilovolt-ampere capacity of a system must increase rapidly with the voltage, the energy expended during a short circuit becomes quite large. For a 220-kv. system, it may be 1 000 000 kv-a.

The transformer cores and coils must be able to withstand mechanically the enormous stresses incidental to short circuits on such systems. These stresses may be many tons. The necessity of high mechanical strength has forced the development of a simple structure with circular coils, which has also made a better transformer electrically. The uniform stack of circular coils greatly reduces the abnormal electrical stresses due to arcing grounds.

Transformers are tested to give a factor of safety of 3.46. When the neutral is permanently grounded to the transformer core, the factor of safety is 2.73.

The bushing by which connection is made between the under oil-winding and the air-insulated line wire is an important part of the transformer, and is designed so that it will arc over on the air end before it will puncture. The arc-over voltage of the bushing at operating frequency is three times the line voltage dry and twice the line voltage wet. The apparent factor of safety is, therefore, 5.19 dry and 3.46 wet. The bushing is designed so that its lightning arc-over voltage is several times the factors already mentioned. The transformer is developed well in advance of the art, and there are no inherent reasons why it cannot be built for much higher transmission voltages, as shown by the fact that the transformers used in the 1 000 000-volt test were of standard design.

Connections.—The method of connecting transformers is of the utmost importance at these high voltages, because if the voltage stresses can be reduced, the reliability of the line will be increased. By connecting the transformers ΔY and grounding the neutral to the core and ground, the maximum normal frequency stresses are reduced 73 per cent. In case of an arc on a non-grounded system, there are very severe high-frequency oscillations which may cause high voltages to ground and, at the same time, turn-to-turn voltages many times more than normal. These stresses are prac-

tically eliminated when the neutral is grounded, as the arc is then non-oscillatory. If a permanent ground is used, only one transformer bushing is required. This also makes possible a transformer construction which eliminates most of the difficult points to insulate, such as creepage over the ends to the core.

The non-grounded system may be either $\Delta\Delta$ or ΔY. If one line becomes grounded, the normal frequency stresses are increased 73 per cent. The resulting arc is oscillatory and produces enormous stresses between turns in the transformer. The turn-to-turn stresses may sometimes be equal to a line-to-line voltage. If an accidental ground occurs, the abnormal voltages usually cause a break-down on another line or a line-to-line short circuit.

Telephones are inoperative during the arcing. With the ΔY grounded neutral systems, there is no dangerous rise in voltage. If the short-circuit current greatly exceeds the capacity current, the arc is practically non-oscillatory. A single-phase short circuit results immediately and is relieved by the relays.

Neutrals are sometimes grounded through resistance, in order to limit the short-circuit current. If the resistance is high, the characteristics are similar to the non-grounded system, and if it is low, the effect is intermediate.

A scheme has been proposed recently for grounding the neutral of the transformer through a reactance coil adjusted to balance or reduce the capacity current in the arc to zero, the idea being to suppress the arc. This may be desirable sometimes on relatively low-voltage systems. On high-voltage systems, it is difficult to make the adjustment within 1 or 2 amperes or close enough to suppress the arc. In case of a ground of one line, the corona loss may become very great, and it is not possible to balance this loss of current by a reactor. This plan produces, in effect, a non-grounded system with an arc suppressor which may or may not be adjusted sufficiently close to extinguish the arc. Its chief use will probably be on low-voltage systems.

Y–Y connections without delta are undesirable and dangerous and will generally cause telephone trouble. The present practice is tending rapidly toward grounded *Y*. The direct grounding of the transformer neutral is a necessity for extreme voltages and is assumed in the discussion for voltages at 220 kv. and more.

Switches.—The main purpose of the switch is to operate under the abnormal conditions of short circuit. At the very high voltages, the energy involved in a short circuit will be great. Switches have been developed to take care of short circuits of 1 000 000 kv-a. and more. It is desirable to keep below these values, however, by sectionalizing and by the use of reactance. The switch problem is a difficult one, because of the energy involved in a short circuit.

Line Conductors.—If voltage is applied between the wires of a transmission line and gradually increased, a point is finally reached at which a hissing noise is audible, and, in darkness, a pale glow will be seen to surround the wires. A considerable loss will be noticed, which will increase

rapidly with increasing voltage. This is the familiar corona. The loss increases as the square of the excess voltage above the starting voltage.

In high-voltage transmission, it is important to be able to predict the corona characteristics of a transmission line. Fortunately, this can be done accurately. The voltage at which corona starts, the loss at a given voltage, etc., under any conditions, can be accurately pre-determined. The chief factors affecting corona formation are the diameter of the conductor, the condition of the conductor surface, the spacing, and the barometric pressure. Variation in conductor diameter has a far greater influence than the spacing. The loss increases during storms.

In order to prevent loss at the higher voltages, a conductor of large diameter is necessary. At 220 kv., at sea level, a conductor about 0.95 in. in diameter is required and, at 5 000 ft., the size would be about 1.20 in. For equal conductivity, an aluminum conductor has a diameter about 25% greater than one of copper, and for this reason, aluminum is sometimes used at high voltages.

A very successful conductor used in California consists of aluminum with a steel core. As the size of a cable is increased, the size of the strands relative to the cable diameter is reduced. As this may have the effect of roughening the surface, and when the corona voltage will not increase as rapidly with increasing diameter for a cable as for a smooth conductor, it is highly desirable to develop a smooth tubular conductor for the very high voltages.

Conductors stranded in various ways have recently been studied. For a given diameter, the maximum voltage is obtained from a smooth tube. For the same diameters, a cable is usually good for only 85% of the voltage of a tube. This ratio is called the irregularity factor. It is of the utmost importance to consider this factor carefully at high voltages.

With conductors about 1 in. in diameter, the 7-strand cable is impracticable. The larger strands become mutilated in manufacture, and the irregularity factor is lower than on cables of a greater number of strands. For new cables, 1 in. in diameter, the irregularity factor was about the same for cables of 19, 37, and 61 strands and varied from 0.80 to 0.85; in new cables, it was generally near 0.80. In some other types of conductors and in mutilated cables, it was lower. The lowest value obtained was approximately 0.70. The irregularity factor probably improves when the points gradually oxidize off with weathering. An aluminum cable of about 1 in. in diameter and several years in operation had a factor of 0.85 or more. The 7-strand cable was not as good, because of the non-uniformity of the cable, due to the stiff strands, and because the stiff strands had become mutilated in manufacture. It is important to have the individual strands of the outer layer free from mutilation and evenly placed. Projecting irregularities should always be avoided. It is also possible to prevent corona loss by using for each conductor three or more wires of the same potential placed closely together. The relative diameters of the two types of conductors at 220 kv. are, as follows, tubular conductor, 0.77 in.; cable, 0.95 in. It is seen that the line conductor presents no special difficulty at 220 kv. Quite satisfactory results can be

obtained with cables of about 1 in. in diameter and spaced 15 ft. apart. For higher voltages, it is simply a question of getting sufficient diameter with a smooth surface.

The corona loss starts at a given point during each half cycle as the voltage increases, continues over part of the half cycle, and, finally, ends at a given point as the voltage decreases. A varying amount of corona and loss thus occurs during a given part of each voltage wave. The conducting corona, in effect, makes a conductor which periodically varies in diameter. The capacity and loss, therefore, vary during parts of each wave. It follows that if a sine-wave voltage high enough to cause corona loss is applied to conductors, the current cannot follow a sine wave, but must be distorted or contain harmonics. These harmonics are highly undesirable from the standpoint of telephones and otherwise, which is, therefore, another good reason for avoiding corona on transmission lines.

The Line Insulator.—The principal cause of the serious insulator failures has not generally been mysterious high voltages, but poor material and poor mechanical designs of units of the cemented type. The Hewlett insulator, which is free from cement and tight-fitting metal parts, has been free from these troubles. During recent years, the cemented-type unit has been improved, and such troubles have been greatly decreased.

There is another problem, however, which becomes of importance at the higher voltages. When insulators are placed in series in a string, the voltage does not divide evenly. A very high percentage is across the unit nearest the line, whereas even distribution would put 10% on each unit of a 10-unit string. When there are more than 5 units in a string, 20 to 30% of the applied voltage will be on the line unit. It is evident that this becomes of great importance at the higher voltages; for instance, at an operating voltage of 110 kv., the stress on the line unit is 19 kv.; at 220 kv., it is 38 kv.

This uneven voltage distribution may be corrected in a number of ways, one of which is by varying the capacities of the units along the string in proportion to the currents. The spark-over characteristics of a string graded in this manner are bad, as there is a tendency to cascade.

The voltage may be distributed by means of the shield which, in effect, eliminates the capacity to ground in that all the units in the string are the same; it eliminates corona and directs the arc away from the string. By means of the shield and standard, well tried insulators, unit stresses on 220-kv. lines are readily reduced below those at present existing on successful 110-kv. lines. By better distribution of the surface stresses on the individual units, the shield also tends to increase the spark-over voltage when the string becomes dirty.

Although there is considerable room for improvement in the line insulator, it appears that insulator troubles will be less than on the lower voltage lines. It seems time to develop a large unit for use on lines of more than 220 kv.

The insulator or bushing is generally selected so that the wet and dry spark-over voltage at normal frequency is several times the operating voltage. The average ratio of the flash-over voltage of a single string to the operating voltage is 3 dry and 2 wet. Experience has shown these values to be necessary

in order to give good operations. It is interesting that a higher "factor of safety" is required at the lower voltages. This would be expected, as all lines are subjected to the same lightning voltages. From 11 to 14 units will be used on 220-kv. lines. The spark-over voltage decreases with barometric pressure.

It is important to discuss the abnormal conditions that occur on transmission lines before deciding on lightning protection.

Abnormal Conditions on Transmission Lines.—The abnormal voltages that are likely to occur on transmission lines and need be considered in connection with the insulator and transformers are as follows:

1.—Cloud lightning in most cases occurs on the line as an induced stroke. A very steep wave-front voltage travels over the line. At one instant an insulator may be subjected to normal voltage and less than a millionth of a second later to the normal voltage plus or minus the lightning voltage. The lightning characteristics of insulator, bushings, and arrester gaps have been thoroughly investigated by a lightning or impulse generator which the General Electric Company has had for a number of years in the High Voltage Engineering Laboratory at Pittsfield. This lightning or impulse generator is capable of producing voltage waves of a known shape and a duration measured in micro-seconds. The range of this lightning generator has been extended from 800 to about 1 500 kv. The current discharge is measured in hundreds or thousands of amperes. This is far in excess of lightning strokes induced on transmission lines and probably approximates voltages on lines caused by direct lightning strokes. Fortunately, the lightning spark-over voltage of an insulator is always higher than the 60-cycle, spark-over voltage. The lightning spark-over voltage is also not affected by rain or moisture. Observations that have been made by placing gaps of various spacings on transmission lines show that the danger from lightning decreases rapidly with increasing line voltage. In general, it was found that the voltages were of steep wave front. Many discharges took place on the lower voltage gaps. The discharges on the higher voltage gaps were less and less until finally few were found at a needle-gap setting for about 200 kv. This, perhaps, would correspond to about 400 kv. in actual volts. A direct stroke, of course, may be higher. In general, the field tests checked the laboratory tests.

2.—Other transients that are of importance on transmission lines are those caused by arcing grounds on systems with isolated neutrals and those caused by switching. Such disturbances as the General Electric Company has been able to measure are either in the nature of a surge or a highly damped high-frequency oscillation. Such disturbances sometimes amount to double-line voltage, but often cause very little rise in voltage across the line. They may build up, however, to high internal values in inductive apparatus. Fortunately, the grounded neutral system is fast replacing the isolated system. The power arc in the grounded neutral system is practically non-oscillatory. For very long lines at high voltage, however, where the capacity current may approach in value the short circuit current, arcs may cause oscillations even on the grounded neutral system.

3.—It can be safely stated that undamped high-frequency disturbances practically do not exist on transmission lines. The spark-over voltage for continuous high frequency is lower than the 60-cycle spark-over voltage. The spark-over voltage of an insulator for any transient disturbance that is likely to occur on a transmission line, is always higher than the 60-cycle spark-over voltage. Insulator failures or spark-overs may be caused by excessive voltages, by weakened insulation, or by a combination of the two. Available data indicate that the greater number of insulator failures have not been due primarily to excessive voltages or to "high frequency", but to weakened insulation.

In parts of the United States having a long dry season, dirt collects on the surfaces of the insulators. When this dirt becomes wet with the first rain, dew, or fog, the surface becomes conducting, and the spark-over occurs at a very low value. It is somewhat similar to placing a fuse suddenly across the string. This trouble may be accentuated when there has been mechanical deterioration, and part of the string has become useless. The proportion of failures is small, because it requires a combination of conditions as to dirt, moisture, etc., to establish a conducting path sufficiently long to cause complete spark-over before the dirt is burned off or washed away. Although it is difficult to trace some of these failures to dirt and moisture, it is significant that such failures do not occur where summer rains are frequent. Such rains not only tend to prevent dust, but also wash away the small quantity that collects. The laboratory data given in Table 2 are of interest in connection with dirt formation.

TABLE 2.

Number of units in series.	Spark-Over Kilovolts.				
	Dry clean.	Wet clean.	Dew clean.	Dry dirty.	Dew dirty.
9	537	380	542	537	160

Laboratory tests do not indicate the true wet arc-over on a wet, dirty insulator unless the power supply and testing transformer are large. The laboratory results are generally too high. Ionization of the air around the line conductor, due to incipient corona or other cause, may be dismissed as a probable cause of mysterious spark-over. Tests made in a closed box, where the ionization was much stronger than would be possible in the open air, showed no reduction in spark-over voltage.

Extra High-Voltage Lines.—From the previous discussion, it appears that transmission at 220 kv., or somewhat higher, offers no difficulty. As 220 kv. was about to be realized, it seemed desirable that an investigation be carried to the extreme, in fact beyond any voltage that economic conditions will probably ever demand. At the High-Voltage Engineering Laboratory at Pittsfield in September, 1921, more than 1 000 000 volts was applied to a short section of a 1 000 000-volt line. In this investigation, tests have been made at

1 500-kv., single-phase, 1 000 kv. to ground, and 1 000 kv. three-phase. Briefly, the investigation, as far as it is completed, shows that the laws of corona determined at the lower voltages are followed at the higher voltages. The calculated sphere-gap curve checks the measured one. The needle-gap spark-over is obtained by extending the lower voltage curve. These data are given graphically in Figs. 7, 8, 9, and 10.

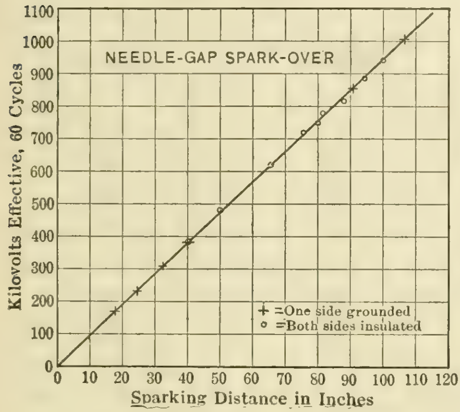

FIG. 7.

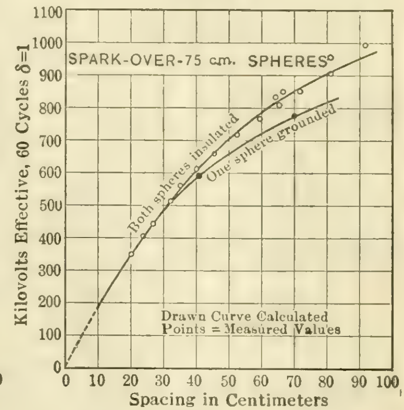

FIG. 8.

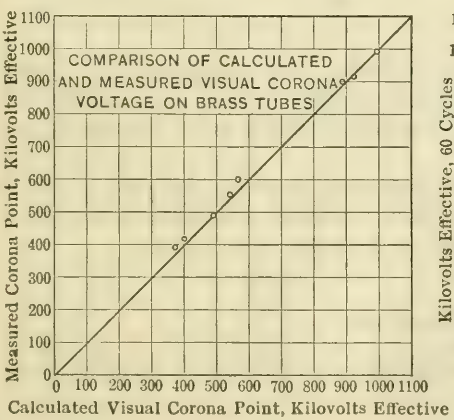

FIG. 9.

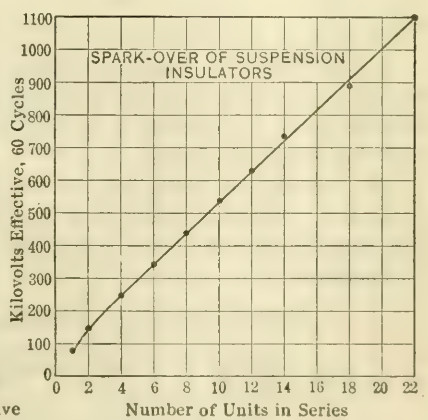

FIG. 10.

In view of this information, it is interesting to discuss the characteristics and practical possibilities of a 1 000 000-volt, transmission line regardless of the fact that present economic conditions do not require such a line. By going to the extreme, a perspective of the whole field will be obtained. The present importance of the problem is to know how to predetermine the characteristics of the higher voltage lines, in order to be ready when conditions demand them. Only the transformer, the transmission conductor, and the line insulator need be considered. The low-voltage apparatus would not differ

from that at present in use, except for the ability to handle, regulate, and control the large amount of energy necessary to make such a line economical. This is the factor that will probably determine the ultimate voltage. The comparison with the 220-kv. line as a background will be of interest.

TABLE 3.—CORONA ON PARALLEL BRASS TUBES, 60-CYCLE, SINGLE-PHASE.

SPACING.		VISUAL CORONA	
In inches.	In centimeters.	Kilovolts, effective, calculated.	Kilovolts, $\delta = 1$, observed.
Diameter, 3.5 in., 8.9 cm.:			
75.5	192	790	730
111.5	283	876	895
147.5	375	915	915
183.5	466	990	990
Diameter, 1.75 in., 4.45 cm.:			
73.7	188	490	490
109.7	279	538	560
145.7	370	568	600
181.7	463	604	675
Diameter, 1.0 in., 2.54 cm.:			
73	185	340	370
109	277	364	380
181	460	402	415

The transformer would not differ radically from the present-day transformer as standard, circular-coil transformers were used in the investigation with more than 1 000 000 volts, single-phase, 1 000 000 volts to ground, and 1 000 000 volts, three-phase.

The calculation of the size of the conductor necessary for such a line is of interest. At sea level and at 30-ft. (9.2-m.) spacing, three-phase, a conductor 5 in. (12.5 cm.) in diameter is necessary at 1 000 kv.

Therefore:

$$e_0 = 21.1\, m_0\, r\, \delta \log_e \frac{S}{r} \text{ kv. to neutral.}$$

$m_0 = 0.90$; r = radius, in centimeters; s = spacing, in centimeters.

$e_0 = 578$ to neutral.

$E_0 = 1\,000$ kv. between lines.

$$p = \frac{244}{\delta}(f + 25)\sqrt{\frac{r}{s}}(e - e_0)^2\, 10^{-5} \text{ kw. per km. per condition.}$$

$$p = 0.08\,(e - 578)^2 \text{ kv. per mile, three-phase.}$$

At 1 000 kv. between lines, the loss is, therefore, zero.

If the voltage is increased 10%, the loss is:

$$p = 0.08\ (635 - 578)^2 = 0.08\ (57)^2 = 260 \text{ kw. per mile}$$

This is quite large. By examining the equation, it will be seen that a peculiarity of the very high-voltage line is that the corona loss increases rap-

idly with a slight increase of the voltage above the critical point. This is so at the higher voltages, because the loss increases as the square of the difference between two voltages. A small increase means a large actual voltage increase.

This is well illustrated by comparing the loss on a 1 000-kv. line and a 220-kv. line for a 10% increase in voltage above the critical value.

For 1 000-kv.:

$$p = 0.08\ (578 - 578)^2 = 0$$

at 10% increase,

$$p = 0.8\ (635 - 578)^2 = 0.1\ (578)^2 = 260 \text{ kw. per mile}$$

For a 220-kv. line:

$$p = 0.05\ (127 - 127)^2 = 0.$$

at 10% increase,

$$p = 0.05\ (130 - 127)^2 = 0.05\ (12)^2 = 7.2 \text{ kw. per mile}$$

Because of the large increase in loss when the voltage is increased, or the critical voltage is lowered, it may be desirable to operate such lines with a larger margin between the critical and operating voltage.

Rain (on the average) lowers the critical voltage 20%; the loss during a storm, therefore, would be:

$$p = 0.08\ (e - 0.8 \times 580)^2 = 0.08\ (116)^2 = 860 \text{ kw. per mile;}$$

a loss of almost 1 000 000 kw. on a 1 000-mile line. For small loss during a storm, it would be necessary to increase the diameter of the conductor to 6.5 in. (16.5 cm.).

In the calculation just given, a fairly smooth tube is assumed. Other forms of conductors are possible. For special conductors or cables, however, it is well to be sure that a decrease in diameter of component parts does not more than offset the gain by the increased total diameter of the complete conductor. The 60-cycle capacity current of such a line would be 4.15 amperes; the kilovolt-amperes per mile would be 7 200 at 60 cycles. The line insulator offers the most difficult problem. The length of the insulator would be from 15 to 20 ft.

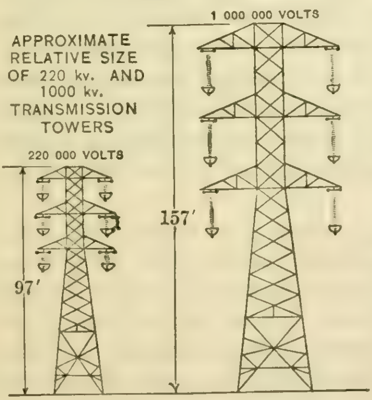

Fig. 11.

A description of a 1 000 000-volt line may now be given: The conductors would be 6.5 in. (16.5 cm.) in diameter, suspended by insulators from 15 to 20 ft. (4.5 to 6 m.) in length, and spaced at least 30 ft. (9.2 m.) apart. A graphical comparison is given in Fig. 11.

Assume that the tubular conductors are made up with a shell equivalent to 1 500 000 cir. mils of copper. At unity power factor per three-phase circuit, 3 000 000 kw. can be delivered 1 000 miles with 1 000 000 volts at both ends of the line and at an efficiency of 88 per cent. The frequency was taken at 25 cycles in the problem just cited (only for illustrative purposes) to avoid the complication of considering wave transmission. The charging current at no load would be 1 500 amperes, with

1 000 kv. at the receiver end and 700 kv. at the generator end. More complete data are given in Table 4 and Figs. 12 and 13. The control and harmless dissipation of the energy due to an accidental short circuit on the buses of such a system is a problem.

TABLE 4.—CHARACTERISTICS OF 1 000 000-VOLT LINE ON THREE-PHASE CIRCUIT, 25 CYCLES, 1 000 MILES, 6.5-IN. DIAMETER CONDUCTOR, 30-FT. SPACING.

KILOVOLTS.			POWER, IN KILOWATTS.		PERCENTAGE, POWER FACTOR.		Percentage of Efficiency.	AMPERES.	
Generator.	Middle.	Received.	Generator.	Received.	Generator.	Received.		Generator.	Received.
Conductor Equivalent to 1 500 000 Cir. Mils, Copper.									
653	908	1 000	97 200	0	+ 5.67	......	0	1 510	0
760	946	1 000	1 392 000	1 250 000	+ 65.6	100	90	1 610	720
1 000	1 008	1 000	3 270 000	2 870 000	+ 97.8	100	88	1 925	1 650
1 400	1 183	1 000	5 890 000	5 000 000	— 97.2	100	85	2 490	2 880
Conductor Equivalent to 500 000 Cir. Mils, Copper.									
665.0	904	1 000	280 000	0	16.7 lead	......	0	1 515	0
870.0	991	1 000	1 710 000	1 250 000	68.4 "	100	73	1 667	722
1 000.0	1 052	1 000	2 578 000	1 980 000	83.3 "	100	75.1	1 800	1 145
1 677.0	1 340	1 000	7 575 000	5 000 000	99.99 lag	100	65.4	2 635	2 885

Line Characteristics.—A careful study of the line characteristics becomes of great importance for long lines and high voltages.

To the present time, good regulation has been effected by the use of synchronous motors or condensers at the receiving end of the line. These machines can be made to take leading or lagging current at will by change of field excitation. As leading current has a boosting effect, the drop at full load may be eliminated by making the machine require leading current under load. The tendency for the voltage to rise at no load is opposed by supplying lagging current. By controlling this current properly, there is no difficulty in keeping the receiver voltage practically constant at all loads with a constant voltage of the generator. It has required a synchronous condenser capacity of from 50 to 80% of the generator capacity to accomplish this regulation. It is well to point out, however, that a considerable part of this has been used to correct the low power factor of the load. This excellent method will be used on the two 220-kv. systems already mentioned.

Generators above a certain critical size are necessary in starting very long lines, otherwise the voltage at the sending end will rise to a high value, even when the generators are not excited. This follows because the slight residual voltage of the generators will cause a capacity current to flow to the line which boosts the generator voltage. The current and voltage will continue to rise to a value depending on the size of the generators. It is desirable to have the generators large enough so that one unit can take care of the charging current of the line. Long lines may be started by bringing up the line and synchronous condensers together.

Single, 60-cycle, high-voltage lines are approaching at present a length of 300 miles. As the length increases a new problem is presented; the line tends to become unstable. The length at which instability occurs depends on the frequency and is due to a peculiar resonant condition that occurs at a critical length. The critical length is approximately 750 miles at 60 cycles and 1 800 miles at 25 cycles. In brief, this condition is due to the fact that it requires time for the electric energy to travel over a wire. With the distances just mentioned, the first wave travels to the end of the line and back to the generator in time to add to the second wave, and so on. These critical distances are called the quarter-wave lengths for 25 and 60 cycles, respectively. Instability will begin to be noticed at distances considerably less than these. At no load and very low generator voltage, the voltage at the far end of such a line would reach high values, being limited, in fact, only by the losses.

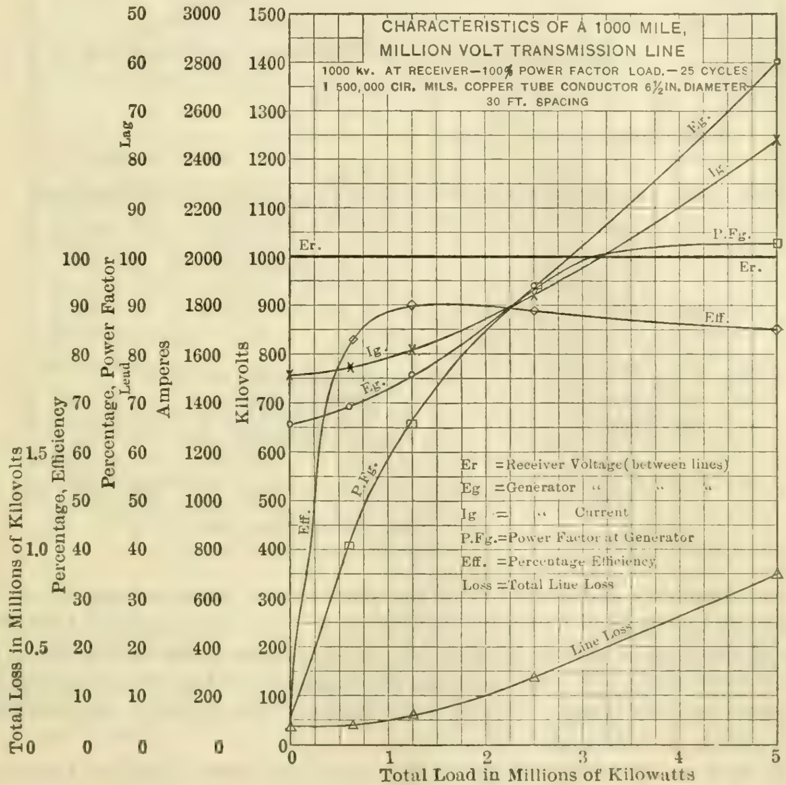

Fig. 12.

It is possible to make use of the peculiar characteristics of such lines. For instance, if approximately constant current is held at the generator, practically constant voltage results at the receiver. Under load, however, the voltage at the middle of the line may be quite high. The characteristics are shown in Fig. 14. At double the distance the half-wave line results. Its char-

acteristics are better than the quarter-wave line. In both, however, there are practical difficulties. The voltage may be high at intermediate points under load and go to very high values at no load. Intermediate taps are also difficult or impossible to make.

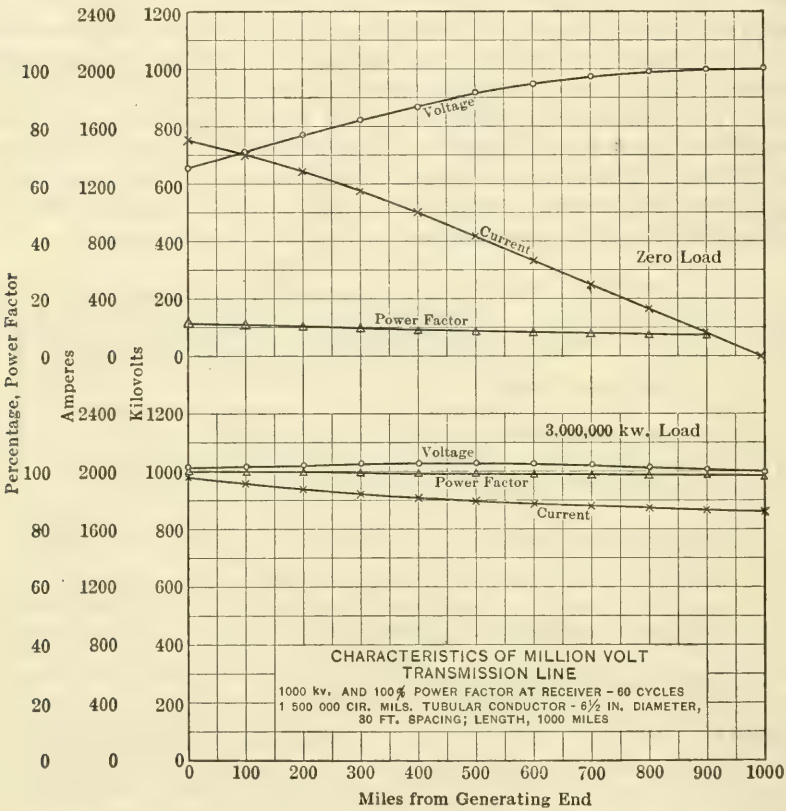

FIG. 13.

The simplicity and flexibility of the synchronous condenser regulated line are lost in quarter and half-wave transmission. This has suggested the extension of the present system by distributing synchronous condensers along the line at intervals considerably less than the quarter-wave length, and controlling the phase relation between voltage and current at these points. Each section is, in effect, an independent short line.

There is no untried principle in this, as synchronous machines have been used and distributed over power systems for years. The plan has been admirably discussed in a recent paper.* This method holds more promise than any of the other schemes considered.

Direct current offers some admirable characteristics for transmission to great distances, which are worthy of mention. The present difficulties come in

* "Regulation and Insulation for Large Power Long-Distance Transmission", by F. G. Baum, M. Am. Soc. C. E., *Journal* of the Am. Inst. Elec. Engrs., June, 1921.

obtaining high direct-current voltages and, later, in stepping down for distribution. For a given distance in air or oil, the direct-current voltage required to cause break-down is about 41% higher than the alternating-current voltage. The advantage of direct current is about 2 to 1 for solid insulations.

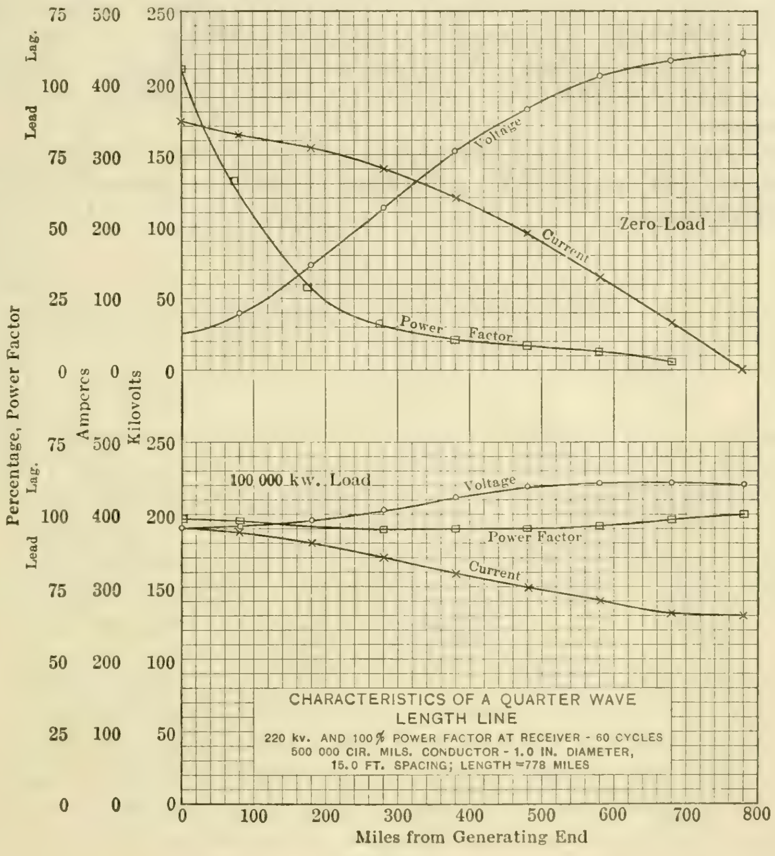

FIG. 14.

It may be of interest to mention that, for every alternating-current line, there is a certain critical current at unity power factor load where the characteristics of the line are the same as for a direct-current line.

Conclusions.—

1.—The maximum voltage used in transmission will not be imposed by engineering difficulties of insulation, but by available supplies of energy. Although it is not probable that economic conditions will require 1 000 kv. for power transmission, the characteristics of such a system have been discussed in order to get a perspective of the whole field. Very high voltages are not economical unless the power is enormous.

2.—Transmission at 220 kv. will generally not be economical unless the power transmitted is of 50 000 to 100 000 kw. per circuit and the distances from

150 to 300 miles or more; at 1 000 kv., economical transmission would probably require more than 2 000 000 kw. per circuit and distances of 1 000 miles, or more. The limitations imposed by the large size of the apparatus units are probably more difficult than those imposed by insulation. A great problem is safe control of enormous amounts of energy during a short circuit.

3.—Considerably higher voltages could be used at present if economic conditions required it. The transformer has been developed far in advance of the art; the line conductor would offer no difficulty; although considerable development is desirable in the line insulator, it does not appear to have serious limitations.

4.—For very long-distance transmission, it appears that stability and good regulation will be secured by distributing synchronous condensers at intervals along the line.

SOCIAL AND ECONOMIC ASPECTS OF HYDRO-ELECTRIC POWER

By Charles D. Marx,* Past-President, Am. Soc. C. E.

All engineers are so firmly convinced of the important rôle which hydro-electric power is playing and will continue to play as a factor in human development, that they do not take time to marshal the facts in support of this statement. An effort to do this, if only in part, will be attempted.

A California writer recently said:

"What is civilization? It's where you stand on a street corner and wait for ten street cars, four hundred automobiles, fifty motor-cycles, twenty-five bikes, a dozen motor trucks, a few fire engines, the police patrol, a hurry-up ambulance, and a funeral, to pass before you dare make a try for the opposite corner."

If that is a correct definition of modern civilization, and indicative of its benefits to mankind, the speaker would not blame Mahatma Gandi for the strenuous efforts he is making, not only to prevent the spread of Western civilization in India, but also to destroy it, through his policy of non-co-operation.

Modern civilization depends on the economic development, transmission and distribution, and the intelligent utilization of the sources of energy for the creation of wealth. Civilizations have existed in the past, and the monuments remaining in India, Egypt, Mexico, Peru, and, later, in Greece and Rome, bear testimony to the ability of our predecessors to utilize some of the sources of energy for the creation of wealth, but also that this energy, largely man power, was not economically employed, and the wealth created was not intelligently utilized, owing to its unequal distribution.

Consider, briefly, the different kinds of energy available for the creation of wealth. There is first the energy exerted directly by man, which was the kind in most general use for the development of ancient civilizations. The amount developed, as shown by the accumulated wealth, depended on conditions of food, climate, and soil, and the ability to overcome physical obstacles. It was large in Asia, Africa, and America, the seats of the most ancient civilizations. The wealth so created, however, was distributed very unevenly, and human energy was often misdirected.

We are told that, "* * * two thousand men were occupied for three years in carrying a single stone from Elephantine to Sais", and that, "to build one of the Pyramids required the labor of 360 000 men for twenty years." Surely this does not represent the economic development of one of the sources of energy.

Modern civilization will continue to depend, at least in part, on the direct utilization of human energy, and the amount available will depend on the population and its physical condition, the latter, in turn, being determined largely by the conditions of living. As bearing on this question of future available man power in the United States, one cannot do better than read

* Prof., Civ. Eng., Leland Stanford, Jr., Univ.; Cons. Engr., Stanford University, Calif.

the article* by Frederic C. Howe, entitled, "Has the Westward Tide of Peoples Come to an End?" He believes that:

"The result of these conditions [from the restrictions on immigration now in force] may be a reduction in the productive capacity of the nation. It will certainly reduce the number of persons occupied in manual pursuits, and especially in the elementary pursuits that are now manned by the raw material from Europe, which for a generation, has been cheaper than the building of machines to do man's work."

If this forecast is correct—and Mr. Howe marshals the facts in support of his conclusion—the importance of conserving all other sources of energy for the creation of wealth will be recognized.

The speaker stresses here, and in his original definition, the creation of wealth as the essential factor in the development of civilization, because the creation of wealth implies a surplus, and it is only when there is a surplus of wealth—a quantity greater than is needed to meet the physical needs of peoples from day to day—that there can be had that leisure for the development of the thinking power of man on which depends both his material well-being and spiritual growth.

The development of the other sources of energy call, in an increasing measure, for the application of human knowledge, in order that a maximum of economic development of these sources of energy may be obtained. "We simply must have cheaper fuel—cheaper energy of all sorts—or every one of us is going to have a harder time making a decent living", says President Little, of the Institute of Chemical Engineers. He claims we must:

"(1) Mine and burn coal more economically; (2) use artificial anthracite in our homes; (3) get more heat out of gas; (4) find a new and better motor fuel; (5) develop more water power."

He shows also that there are other untapped sources of heat and power among which are:

"(1) The immense energy of the sun's rays; (2) the energy of the earth's rotation; (3) the power of the rising and falling ocean tides; (4) the steam of volcanoes; (5) the vast forces stored in the atom."

Among the sources of energy one must distinguish between those the utilization of which spells a destruction of the capital of energy, and those which may be said to be self-renewing. The continuity of civilization depends on the economic utilization and development of the latter classes. Of these, the one most developed at present is the energy obtained from falling water. The others depend on the growing knowledge and skill in making available the other potential sources of energy. Progress in the arts and sciences requires time, and should this progress be slower than the consumption of energy from sources which connote a destruction of the sources of energy, civilization would not only come to a standstill, but would also face destruction. It is because of the self-renewing energy of water that hydro-electric development becomes a factor of such supreme importance for the civilization, not only of this country, but also of other countries where only a beginning of its use is taking place.

* *Scribner's Magazine*, September, 1922, p. 362.

The speaker has briefly referred to India and the efforts being made there to arrest the progress of modern civilization and to turn back to a type for which the claims are made that it is better and more conducive to the happiness of the human race than that now being developed. White Khaddar hand-woven cloth, made of hand-spun yarn, is to take the place of modern cloth; railroads, telegraphs, modern methods of transportation, disseminating knowledge, increasing the productivity of the soil, sanitation, increasing the length of life, and bettering the living conditions of the people, are to be scrapped, for the purpose of holding a civilization that has been static for thousands of years—a civilization of a type that spells poverty for the many and the degradation of humanity. This is a doctrine preached to hundreds of thousands in India, by a man who arrives to do his preaching in a Ford motor car!

However, the prophets of modern civilization in India, the engineers, are busily engaged, through the development of hydraulic power, in bringing about a change in this civilization—a change for the better. The late Mr. Robert Batson Joyner, in his paper on "The Tata Hydro-Electric Power-Supply Works, Bombay,"* describes the improvement of Indian conditions by water power, as follows:

"The work now described shows that, given head enough, it is financially possible at certain favorable places, to store water to provide power during about three-fourths of the year when the rivers are dry, and India should now be able to supply itself with many articles which hitherto have had to be imported; because, though so much of the raw materials is grown in the country, and labor is cheap, power from coal is much too expensive in most parts of India to enable it to compete with other countries, especially as the cost of ocean freight has been so much reduced. The cheap water-power now shown to be producible at favorable sites should greatly promote the prosperity of the country, not only by the establishment of large factories, but also by the use of the stored water, after giving up its power, to help to ward off famine. It should also ensure the growth of the raw materials required, provide transport for these materials to, and for finished products from, the factories, produce the fertilizers needed, and supply food and drink as well as light to the workers and others."

One of Ghandi's cries is "Swadeshi", which might be translated, "India for the Indians." This is a legitimate desire for any nation, and the British hydraulic engineers, with the hearty support of the much maligned British Government, are helping the Indian people toward a realization of this dream. The opposition of some of the Indian people toward Western civilization, and the charges brought against it, however, should cause no wonder. One needs go back no farther than 1770, when there was a widespread feeling that civilization was not all that it might be; that civilized man fell short of the ideal. Mr. J. C. Squire, in the *London Observer,* reviewing Professor Tinker's book, "Nature's Simple Plan, a Phase of Radical Thought in the Mid-Eighteenth Century", states, "It was very generally held—even to-day the dispute is a familiar one in school debating societies—that the savage was better off than the civilized man; happier, stronger, more genuinely poetical. The noble savage was one ideal." Even, to-day, the tales of the South Sea Islands might lead people to think that happiness is in direct pro-

* *Minutes of Proceedings,* Inst. C. E., Vol. CCVII (1918–19, Pt. 1), p. 53.

portion to our ignorance of the powers of Nature, and our ability to utilize them for the benefit of Man.

These views are often held by those who are benefiting most by what the engineer has done in unlocking the stores of energy and making them the servants of man. Literary scribblers, in steam-heated dwellings, with all the modern conveniences at their call by the pressing of a button, and ignorant of the high mental development back of the button which places these conveniences at their disposal, inveigh against modern civilization and its materialistic tendencies. They lose sight of the fact that it is the creation of surplus wealth by the utilization of Nature's energy which makes their existence possible and has raised them from the condition of savages to that of civilized men.

Another interesting development of hydraulic power, which may change the conditions of civilization in Palestine, is that which contemplates the utilization of the waters of the Jordan and other rivers in that country for the generation and distribution of electric power.* The engineer who is urging this development claims that, as regards Palestine, the British mandate, although important, is less so than the hydro-electric development for bringing about peace and prosperity there. "What the mandate is to mean," he says, "depends on the future of hydro-electric power. Make that cheap and accessible and the mandate can prove itself by the economic prosperity it will bring." Mr. Rutenberg insists that the evolution of the scheme is one of the real ways to remove the existing barriers between the Jews and the Arabs. "Offer them the chance of continuous labor," he says, "let them see the obvious economic advantages of the scheme, and they will cease to debate idle differences of principle that have no substantial reality." If hydro-electric power development can successfully wipe out hatred of race and creed, as claimed by Mr. Rutenberg, might it not be desirable to push its development wherever possible in other centers of strife? "La Houille Blanche", the white coal of France, if utilized, might diminish that country's longing for the black coal of the Ruhr, and if there are water-power possibilities in Ireland, peace might even come to that distracted country.

This discussion so far has been confined to the presentation of the economic and social aspects of hydro-electric power, in reference to nations with a civilization differing from our own. The effects of such development are likely to be far-reaching and beneficial. The speaker has merely advanced a claim, but a claim which he thinks can be substantiated as one turns to an investigation of what the development of hydro-electric power has meant in the United States.

Probably no man is better qualified to speak of the effect of electrical engineering on modern civilization than Mr. Charles P. Steinmetz. In an address† before the Franklin Institute in 1914, he stated that:

"The necessities of civilized life consist of two groups: materials, and energy. Our transportation system takes care of materials, but can not deal

* An article on the technical features of the proposed development has been published in *Engineering News-Record*, July 22d, 1922.

† "Effect of Electrical Engineering on Modern Industry", *Journal* Franklin Inst., Vol. 177 (1914), p. 115.

with the supply of energy, and the failure of an efficient energy supply has been and still is the most serious handicap which retards the advance of civilization. The transportation system could deal with the energy supply only in an indirect manner, by the supply of materials as carriers of energy, and when our railroads carry coal, it is not the material which we need, but the energy which it carries. But this energy is available only to a very limited extent, as heat, and as mechanical power in big steam units: most of the demands of civilized life could not be satisfied by it. In any country village far away from the centers of civilization we have no difficulty to have delivered to us any material produced anywhere in the world; but even in the centers of civilization we could not get the energy to run a sewing-machine or drive a fan without electric power. Thus, just as our steam railways and express companies take care of the transportation and distribution of materials, so civilization requires a system of transmission and distribution of energy * * *."

The speaker stated in the beginning of his paper that civilization depends on the economic development, transmission, and distribution of energy, and, furthermore, he called attention to the fact that the store of such energy must not be diminished, if civilization is to endure. It is because of the fulfillment of this last condition, that hydro-electric power plays the important rôle it does in modern civilization.

The economic development and utilization of hydro-electric energy is conditioned on a number of factors. The cost of production, aside from the cost of construction of the plant, is a function of its rate of use, as thus far the development of the storage battery has not progressed sufficiently to be considered for the storage of electrical energy on a large scale. Hence, it is desirable for the most efficient utilization of electrical energy, that there be created a uniform demand or load curve. F. G. Baum, M. Am. Soc. C. E., has shown in an interesting paper,* how electric transmission provides the elastic medium for exchanging any kind of mechanical power to any other form of mechanical power at some point in the system; and also how the inter-connection of a hundred small plants by an electric transmission system with a large power demand, inevitably leads, in order to obtain economy in operation, to the installation of a few large units to supply the entire system. The inter-connection of these large power units, in turn, will permit of an economic utilization of all the power developed, as was shown clearly by the results obtained during the World War, when the people of California faced a power shortage.

Under modern industrial conditions, electric power has a large rôle to play, not only in conserving the energy supply of the nation, but in increasing the amount of man-power energy available by increasing the food supply. All the free land of America is gone. Intensive cultivation must take the place of wastefulness in production which has characterized American farming; but intensive cultivation in the absence of adequate man power means that many things now being done by hand must be done by machines. Then, too, there is a steady disinclination on the part of the people of this country to do ordinary manual work. Electrically operated machines in many industries will lead to a substitution for this man power; even in domestic science, one

* "The Economic Value of Electric Transmission", *Journal of Electricity, Power, and Gas*, January, 1914.

finds the great rôle which the application of electricity is now playing and will continue to play, with increasing importance. The housewife, for her domestic duties, cannot hire a human servant as willing as electricity, with its constant novel adaptation to her needs. Electricity solves in a large measure the vexing problem of domestic help, and brings about a far-reaching change in our daily life. The servant class, as a class, is likely to disappear, and who will say that this is not a social change for the better?

Not only in the food-producing field of agriculture and the food-consuming, energy-producing home, must one look forward to added conservation of human energy. All industry demands the replacement of man power by machinery, and hydro-electric energy is being utilized, both as a conservator of energy, from other sources, and as a converter of minerals and the constituents of the air into fertilizers and other products for the use of man. The field of application is almost limitless, and as it steadily widens, as the intelligence of man, with its constantly developing inventive genius, succeeds in making not one blade of grass grow where none grew before, but many thousands of them, the burden and drudgery of mankind for gaining a daily living will be lightened.

Modern civilization depends on the economic development, transmission and distribution, and the intelligent utilization of the sources of energy for the creation of wealth. The speaker has stated advisedly, the intelligent utilization of the sources of energy for the creation of wealth, because he believes that this intelligent utilization carries with it the intelligent distribution of the wealth so created. Therefore, he believes that the development of hydro-electric power will help solve this vexing problem.

As conditions of living on the farm are made more attractive, as drudgery grows less, and loneliness disappears, as the opportunity of being an owner of land, and not a tenant farmer, becomes greater, as the result of intelligent colonization schemes, such as have been carried out at Durham and Delhi, in California, under the wise leadership of Elwood Mead, M. Am. Soc. C. E.; as such changes are brought about—and they are made possible largely by the use of hydro-electric energy—the creation of wealth is furthered, and its intelligent distribution is accomplished.

Dr. Mead reports*:

"Two canny Scotch farmers came to look over these settlements. One of them went to the back door of one of the farm laborer's homes, and the story of the wife of that farm laborer, will be his text in Scotland. Telling one of his impressions he said, 'I want to say, I have visited all the agricultural countries of Europe. I have visited a great part of the world, but I am going home to tell our people that the finest thing in rural democracy that I have ever seen, are the farm laborers' homes in that settlement at Durham.'"

In California, at least 1 500 000 acres are under irrigation by water electrically pumped, and 83% of the dwellings are wired for electricity. The domestic heating load grows. The use of hydro-electric power for industrial purposes shows a steady increase, and this means that other sources of energy are being conserved and wealth produced without a corresponding loss of

* *Transactions*, Commonwealth Club, November, 1921.

energy. It proves that for that part of the United States—and what is true there holds true elsewhere—the conservation of energy made possible by the use of hydro-electric power, tends to insure the permanency of a civilization which, although perhaps not ideal, has after all changed the conditions of living of millions of people for the better.

The speaker believes he has shown, if only imperfectly, that in the social and economic changes which are taking place, and by which the state of civilization is measured, hydraulic power has played an important rôle; and that it will play an increasingly important one, he firmly believes.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

LOCOMOTIVE LOADINGS FOR RAILWAY BRIDGES
Discussion*

By Messrs. O. H. Ammann, Henry B. Seaman, Charles A. Mead, Herbert C. Keith, Philip George Lang, Jr., H. T. Welty, Clement C. Williams, Jonathan Jones, Glenn B. Woodruff, T. Kennard Thomson, C. R. Young, Edward Godfrey and A. F. Robinson.

O. H. Ammann,† M. Am. Soc. C. E.—The loadings proposed by Mr. Steinman unquestionably have the advantage over the Cooper loading of greater simplicity. This advantage, however, would not be sufficient to justify the abandonment of a loading which has been widely adopted as a standard. Tables and diagrams for the Cooper loading, including those of the author for equivalent uniform loads, greatly simplify the calculation of stresses for that loading.

Examination of the elaborate data contained in the paper has not convinced the writer that the Cooper engine loading is less representative of actual engines than that proposed by the author. On the contrary, he is more convinced than ever that it is futile to attempt to introduce a loading which embodies any marked improvement over that of Cooper.

Consider, first, the engines alone as affecting spans up to about 120 ft. The author's engine bears no greater similarity than does that of Cooper to any of the seven heaviest existing engines, not to mention the many other heavy engines, steam and electric, still in use, and those likely to be evolved in the future.

The apparent improvement of the author's loading over the Cooper system is due to inconsistent presentation of the facts. The author condemns the Cooper loading on account of its discrepancies with existing individual heaviest engines, and emphasizes the close agreement between his M-60 loading and the composite of heaviest existing locomotives. He does not disclose the equally large discrepancies between the M-60 loading and individual heaviest existing

* Discussion of the paper by D. B. Steinman, M. Am. Soc. C. E., continued from October, 1922, *Proceedings*.

† Cons. Engr., New York City.

engines, nor the equally close agreement between the Cooper loading and the composite of heaviest existing engines. All these facts are clearly shown on the two diagrams (Fig. 14), which are self-explanatory. These diagrams also show the small differences (only up to 6% for shears and 7% for moments) between the M-60 loading and its average equivalent, the Cooper E-72 loading.

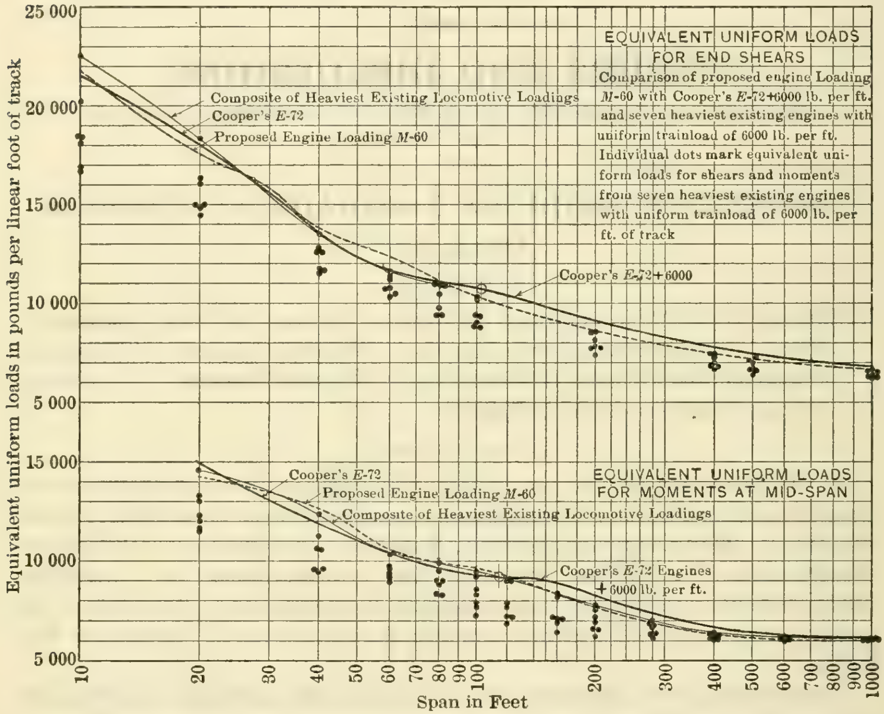

FIG. 14.

Considering the fact that differences between individual existing engines are several times larger, and also the many other uncertain factors, such as impact, wind, secondary stresses, quality of materials, etc., which factors, as variously specified, give, for the same live load, sections differing by as much as 40%, do these small differences between M-60 and E-72, even if they were improvements, justify the abandonment of an established loading?

Consider the combined engine and uniform train load: The apparent discrepancy between the Cooper loading and actual engines in short and long spans is not due to the Cooper engines, but to an inconsistent combination of the engines and the uniform train load behind them. To represent the heaviest modern engines with a train load of 6 000 lb. per ft., as assumed by the author, and to compare equitably with the M-60 loading, the Cooper E-72 engines should be combined with the uniform train load of 6 000 lb. If that is done the apparent discrepancies of the Cooper loading and the existing heaviest loadings, for short and long spans disappear, as may be noted in Fig. 14. The

Cooper curve is as smooth and follows as consistently the curve of composite heaviest existing loadings as the curve of the M-60 loading. Is there any guaranty that the weights of locomotives and cars will not continue to increase at different rates? If that should be the case, the author's loading would become as inconsistent as that of Cooper, unless its axle concentrations were also changed in a ratio different from that of its uniform train load. It is impossible to have an ideal loading for all conditions and all times. Loadings must be changed from time to time, but such changes should be made with the least possible disturbance of the generally adopted standard, unless commensurate advantages can be gained otherwise.

The writer would recommend the retention of the Cooper loading, but would leave the variation of the engine concentrations and the uniform train load by suitable, not necessarily the same, ratios to the discretion of the engineer. Such a specification would be sufficiently elastic to cover practically any present or future loadings. This suggestion is not new, a different ratio for engine concentrations and uniform train load has already been used, notably in the design of the Metropolis Bridge.

The writer would favor a formula for uniform load, except for the fact that such a formula does not convey to the mind a conception of the loading which it represents, and which is desirable for general comparison with actual engines. The author deserves much credit for his elaborate investigation without which proper judgment of this question would hardly be feasible.

Henry B. Seaman,* M. Am. Soc. C. E.—The speaker wishes to express his appreciation of this paper. To have the subject presented in such detail is a great satisfaction.

The next question is its practical application and introduction. Bridges generally, throughout the United States, are rated on the Cooper E system; all the records are on that basis, and to make such a radical change would hardly seem justifiable. The speaker decided, therefore, to propose a double specification,† providing for a multiple of either the E-10 or the M-10 loading, whichever may be preferred by the designing engineer.

It is believed that future heavy bridges will be designed for the M-loading. It will not be difficult to alter the classified records of the railroads if the engineer so desires, as tables are furnished for that purpose. Mr. Steinman is to be congratulated on the results of his studies.

Charles A. Mead,‡ M. Am. Soc. C. E.—The necessity for revision of the live loading for railroad bridges is becoming more and more apparent. Every one who has investigated the stress-producing effects of actual modern engine loads on existing bridges that were designed for the Cooper loading, must be impressed with the lack of uniformity of stress throughout the various parts of the structure. This has resulted in wasted metal in some parts and insufficient section in others, the differences assuming a magnitude beyond the

* Cons. Engr., New York City.

† *Proceedings,* Am. Soc. C. E., April, 1922, p. 948.

‡ Chf. Engr., Div. of Bridges and Grade Crossings, State Board of Public Utility Commrs., Newark, N. J.

E-50 class, which makes imperative some changes in loading specifications to fit modern practice.

It is evident that train loads and locomotive loads do not vary in the same ratio. Train loads in general use are fairly well fixed, owing to the interchange of cars, so that comparatively unimportant branch lines and secondary railroads, with light motive power, will be subjected to the same train loading as the main lines with their heavy power. At present, train loads do not exceed 6 000 lb. per lin. ft. of single track, except in a few instances which will not affect the conclusions reached. Furthermore, the present design of cars must be changed so radically, in order to increase this train loading, that it seems as if this uniform load would represent a maximum train loading for an indefinite period.

Locomotive loadings do vary greatly on different roads and on the several sections of the same road, and necessarily so for economic reasons. Therefore, it is inconsistent that locomotive and train loads should be considered to vary proportionately. Mr. Steinman has gone a long way toward adjusting this incongruity. He has also produced a simple specification requiring a minimum amount of work in computation.

Good bridges can be designed for a uniform load plus spot loads, as suggested in Mr. Steinman's second series. This method is not new, but it has been presented in this paper more comprehensively than ever before. The selection and spacing of spot loads can be adjusted to suit the loading requirements of various railroads, resulting in more economical bridges. From its simplicity and its adaptability to various conditions, the second loading method is especially attractive.

Mr. Steinman deserves the gratitude of the Profession for presenting this subject so comprehensively, and is to be congratulated on the excellence of his paper.

HERBERT C. KEITH,* M. AM. SOC. C. E.—The author is to be congratulated on his paper; but bridge engineers are more to be congratulated on his having presented to them in this paper the results of his studies.

In 1882, under the direction of the late Samuel E. Tinkham, M. Am. Soc. C. E., the New York and New England Railroad Company adopted bridge specifications with a live load headed by a consolidation locomotive—a new type at that time—with a driving wheel load of 24 000 lb. per axle, or 96 000 lb. total weight on the drivers. A short time afterward, Mr. Tinkham thought it advisable to increase the engine load to 25 000 lb. per driving axle, or 100 000 lb. on all the drivers.

When it is noted that one of the engines mentioned by the author has a load of 300 000 lb. on the drivers, and another has an axle load of 78 000 lb., it is amusing to one who remembers the criticisms that were made at the time Mr. Tinkham and the New York and New England Railroad Company saw fit to increase the weight on the drivers, in their specifications, to 25 000 lb. per axle and 100 000 lb. total driver load. At that time, many railroad men

* Cons. Engr., New York City.

said that such a heavy engine would never be built; and as the New York and New England Railroad Company was not very prosperous in those days, it seemed somewhat ridiculous to them that such a poverty-stricken railroad, should use such heavy loads. Within three years that road had engines in use heavier than those that had been considered as excessive. The changes of the future cannot always be foreseen. There have been periods when the weights of locomotives have increased, and these periods have been followed by a slackening off in the rate of increase of locomotive loads, during which the weights of cars have been increased, as when the large high-sided coal cars came into use, until now an equivalent to 6 000 lb. per ft. is a commonly accepted train load.

A few years after Mr. Tinkham left the New York and New England Railroad Company, a serious accident occurred near Boston, Mass.—Bussey Bridge collapsed under the weight of a train. This accident caused an investigation to be made by the company of the condition and capacity of its bridges, and the speaker was appointed to that task. He first studied the various engines used on the road, especially the heaviest of each type; there were consolidation engines, Moguls, and the American type with only two driving axles. It was found that in bridges carrying all these engines, the maximum stresses in different members was caused by different types of engines; that is, one member might receive its maximum stress from a consolidation engine, whereas some other member would be stressed more by a Mogul or an American engine. In some cases a member would receive its maximum stress from a lighter, but more compact, engine, than from the heavier, but longer, engine of the same type. It would have been quite a task to make calculations for all the bridges for all these locomotives; therefore, after some study, it was decided to use as a basic load for this investigation, a uniform load of 4 000 lb. per lin. ft., which was the recognized heavy train load at that time, with an excess load of 3 000 lb. per lin. ft. for a length of 25 ft. For the purpose of comparing the effect of the different locomotives, tables were prepared, that gave, for different lengths of span and different positions in the span, the relative moments and shears of various heavy locomotives that were used on different parts of the road, as compared with the basic loading of 4 000 lb. per lin. ft., with an excess load of 3 000 lb. per ft. for a length of 25 ft. This loading was adopted also as the standard for the design of new bridges on the road until the New York and New England Railroad Company was absorbed by the New York, New Haven, and Hartford Railroad Company.

It is interesting to note, however, and it is considered to be worthy of serious thought in connection with the model loading which Mr. Steinman has suggested, that although the heaviest locomotives may not run on the minor branch lines, there may be short trains of heavy cars hauled by a lighter locomotive on those lines. Instead of increasing, as was suggested, from the M-60 to the M-75 or the M-90 loading, it might be advisable to take cognizance of the fact that, on the branch lines, light locomotives may haul trains made up of cars as heavy as those on the main lines with their longer trains and heavier locomotives. This matter should receive careful consideration.

PHILIP GEORGE LANG, JR.,* M. AM. SOC. C. E. (by letter).†—For more than a generation the Cooper loadings have represented to American engineers the accepted medium for determining and recording the carrying capacities of bridges. A careful perusal of Mr. Steinman's paper indicates that it is primarily an attack on the Cooper system of loading. Certain particularly heavy engines in actual use have been selected, and an attempt has been made to develop a loading to represent the composite of these engines. The actual engines selected are extreme, and are used in special localities for special purposes.

Why such a special engine loading as M-60 should be followed by a train load of 6 000 lb. per lin. ft. is not apparent. As special engines were selected for study and comparison, there is no reason why similar cars should not likewise have been selected. Cars are in use on American railroads, that average 8 300 lb. per lin. ft. of track, and others have been proposed of more than 10 500 lb. per lin. ft. The Cooper loading provides for an increase in the following train load and thus tends to bring the average train load up to that of the engine load. The M-60 loading perpetuates a material difference in the effect of the engine and the train load on bridge structures.

The author states that "since the days of the E-40 loading, the axle concentrations have increased 100%, whereas the weight of train load per linear foot has increased barely 50 per cent."

It would seem that such a statement is open to question. Although, perhaps, the engine axle concentrations have increased 100% the weight of the train load per linear foot has increased about in the same proportion; certainly 30 years ago, cars having capacities of 20 and 30 tons were common; to-day, cars with capacities of 55 and 70 tons are in general use, and many cars with capacities of 100, 110, and 120 tons are in operation and proposed for general use.

Again, the author states that "it [the new loading] should be from 25 to 50% heavier than the average present loading." Just what is meant by this statement is not readily discerned. The engines investigated by the author have an effect on bridge structures approximately equivalent to Cooper's E-73; which is equivalent to the M-60 loading, with the exception that the author's loading provides for a train load of 6 000 lb. per lin. ft., whereas the Cooper loading provides for a train load of 7 300 lb. per lin. ft., which more nearly approximates present-day equipment and rolling stock.

The simplified loading and the load formula are essentially an M-60 loading. Each of these forms is merely a return to the old and, perhaps, original idea of simplified loading to be used in order to make for ease in calculation. Such a loading has no basis in fact, and is simply prepared with the idea of making it produce stresses in bridge structures approximately equivalent to the motive power and rolling stock in use, or, in this case, approximately equivalent to the proposed typical engine designated as "M-60". There does not seem to be any valid reason for the use of such a so-called "simplified" form of loading, and when a typical loading for the design and re-calculation or the rating of

* Engr. of Bridges, B. & O. R. R., Baltimore, Md.

† Received by the Secretary, September 7th, 1922.

bridges in service is determined, a complete set of moment, shear, and floor-beam reaction tables may be prepared. Such tables for the Cooper loadings have been in use for many years and simplify the calculations; certainly, as much so as the proposed simplified loading or the load formula.

It will be shown that the loading proposed by Mr. Steinman does not vary appreciably from the Cooper system of loading, and that the Cooper system represents the actual loads in service more nearly than the proposed M-60 loading.

In Table 10 is given the moments and shears for span lengths varying from 10 to 300 ft. The equivalent uniform load is shown for the E-60 and the M-60 loadings and also the actual E-rating for M-60 and the E-rating for M-60 as given by Mr. Steinman. The E-ratings given in the paper differ from those computed by the writer. For moments, with the span lengths shown, this difference ranges from 0.6% to 14.2%, with an average of 3.1%, and for shears from 2.4 to 7.4% for span lengths varying from 10 to 80 ft., with an average of 5.25 per cent. It would seem that this constitutes a rather remarkable variation where an effort is made to supersede the existing Cooper loadings.

TABLE 10.—Comparative Table—Moments and Shears.

	Moments					Shears					
Span, in feet.	E-60, equivalent uniform load.	M-60, equivalent uniform load.	E-rating for M-60.	E-rating shown in Table 2.*	Percentage of variation.	E-60, equivalent uniform load.	M-60, equivalent uniform load.	E-rating for M-60.	E-rating shown in Table 2.*	Percentage of variation.	Span, in feet.
10	7 500	7 880	63.0	72	14.2	9 750	10 880	67.0	72.0	7.4	10
20	6 190	7 125	69.1	73	5.6	7 500	8 815	70.5	74.0	5.0	20
30	5 475	7 000	76.7	74	3.8	6 300	7 915	75.5	73.0	3.3	30
40	4 920	6 340	77.3	75	3.0	5 655	7 120	75.6	72.0	5.0	40
50	4 565	5 715	75.2	73	3.0	5 235	6 480	74.3	70.0	6.1	50
60	4 330	5 335	73.9	72	2.6	4 900	6 190	75.8	71.0	6.8	60
70	4 180	5 100	73.1	72	1.6	4 740	5 940	75.2	71.0	6.0	70
80	4 050	5 000	74.1	73	1.5	4 660	5 650	72.7	71.0	2.4	80
90	3 950	4 935	75.0	73	2.7	4 565	5 335	70.0	70.0	....	90
100	3 865	4 830	75.0	73	2.7	4 500	5 160	68.9	69.0	....	100
120	3 845	4 615	72.1	71	1.7	4 340	4 920	68.0	68.0	....	120
140	3 790	4 420	70.0	69	1.4	4 200	4 720	67.4	67.0	....	140
160	3 730	4 200	67.6	68	0.6	4 100	4 555	66.7	67.0	....	160
180	3 640	4 025	66.3	67	1.0	4 000	4 415	66.2	66.0	....	180
200	3 555	3 865	65.2	66	1.2	3 920	4 300	65.8	66.0	....	200
250	3 370	3 545	63.1	65	3.0	3 765	4 075	64.9	65.0	....	250
300	3 255	3 310	61.0	63	3.2	3 640	3 915	64.5	65.0	....	300

Note.—E-60 = two of Cooper's E-60 engines, followed by 6 000 lb. per ft., or two 75 000-lb. axle loads, 7 ft., center to center.

* *Proceedings*, Am. Soc. C. E., May, 1922, p. 1050.

The statement has been made that "the proposed loading has much to recommend it, particularly as applied to design. It more nearly represents future developments in train load to be expected in this country, and insures a more uniform design of bridges."

It is doubtful whether such is the fact. The M-60 loading approximates the heaviest engines now in use, but is followed by a train load of 6 000 lb. per lin. ft. of track, which does not represent present-day maximum train loads. There is, therefore, too great a disparity between the engine and the following

load in the case of the M-60 loading. This disparity does not exist with the Cooper loading, particularly when M-60 and the present loadings are compared with Cooper's E-73.

Fig. 15 shows moments and shears for existing heavy engines and the three forms of the author's proposed loading in comparison with Cooper's E-73. The stress-producing effects of the heavy locomotives approach Cooper's E-73 for the longer spans if the following train load is increased. It may also be noted that the actual engines are represented more nearly by the Cooper E-73 than by the M-60 loading. For moments, the variation of the actual heavy locomotives from E-73 is from 4 to 13%, whereas for M-60, the variation is from 6 to 16 per cent. For shears, the variation of the actual engines is from 1 to 12%, whereas for the M-60, it is from 4 to 12 per cent.

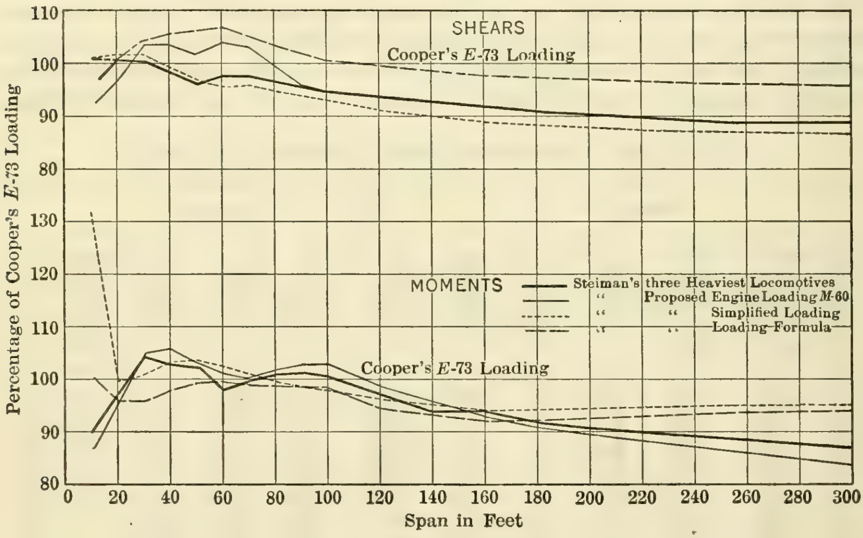

FIG. 15.

The further statement has also been made:

"In view of the present universal use of Cooper's loading, it may well be continued for the classification of old structures, in spite of some of the shortcomings pointed out by Mr. Steinman, but there is clearly need for something other than the short Consolidation locomotives of the Cooper series when it comes to proportioning the parts of a new bridge."

Evidently, it is proposed to use one method or system for the design of new structures, and to continue in use a different system for the rating of existing structures and for the determination of their carrying capacity. This would require a structure to be re-calculated for the other system. The bridges now in service cannot be re-calculated for a new system of loading. The work involved is too great, and engineers in charge of railroad bridges have not the time to change the records. Statistics indicate that there are about 250 000 bridges in use on American railroads. Presumably, complete records and calculations for these bridges exist.

In a study of the length of bridge spans, more than 5 000 railroad bridges have been classified, this study being representative of general bridge conditions in the United States. Exclusive of timber trestles, it was found that these bridges might be classified as to span as follows:

Less than 120 ft.	96%
From 120 to 149 ft.	1½%
" 150 to 199 ft.	1%
" 200 to 249 ft.	1%
" 250 to 300 ft.	4 spans
More than 300 ft.	11 spans.

It is apparent from the foregoing tabulation that the plate girder is the most prevalent type of bridge. Spans in excess of 120 ft. are relatively few, and, undoubtedly, the few bridges that exceed 300 ft. in length, when designed and built, are the subject of special consideration. The 1920 A. R. E. A. Specifications for Steel Railway Bridges treats of spans up to 300 ft. in length. In view of the classification of bridges mentioned previously, this discussion has been limited to the consideration of spans of less than 300 ft. Fig. 15 shows that for spans from 10 to 120 ft., there is practically no variation between the Cooper series of loadings, the engines in use, and the author's proposed loadings—certainly not sufficient variation to justify the adoption of a new system of loading.

In this connection, not only structures to be designed in the future must be considered, but also the vast number of existing structures in use, for which elaborate records are maintained in order that motive power may be assigned so as to secure the maximum benefits, considering the ultimate carrying capacity of the structures.

The author's study is appreciated, particularly as it has the effect of drawing attention to the question of the load to be used in the design of railroad bridges. Except for the advantage to be derived from such discussion, it is not felt that a convincing argument for discarding the Cooper system has been developed.

H. T. Welty,* M. Am. Soc. C. E. (by letter).†—The author is to be complimented for his valuable contribution to this subject, which, in the writer's opinion, constitutes a strong argument in favor of retaining the Cooper system of loading, with possibly a modification in the uniform load following the series of wheel loads.

Many diagrams are shown, which will be of great value for reference, but to the writer, the most illuminating data are those given in Table 2‡ showing equivalent Cooper ratings for various spans of the proposed composite loading, M-60. The majority of railroad bridges have span lengths of less than 100 ft. It will be seen by referring to Table 2 that the moments produced by the M-60 loading for such spans are equivalent to Cooper's E-73 for spans of 20, 50, 80, 90, and 100 ft., and vary, for the others, from E-73 by less than 3 per cent.

* Engr. of Structures, N. Y. C. R. R., New York City.

† Received by the Secretary, September 8th, 1922.

‡ *Proceedings*, Am. Soc. C. E., May, 1922, p. 1050.

Even for spans up to 160 ft., the variation is only 7%, and this is because Mr. Steinman uses a uniform load of 6 000 lb. per lin. ft. for his M-60 loading, whereas the Cooper E-73 would carry with it a uniform load of 7 300 lb. per lin. ft. Should the Cooper loading be modified to the extent of using 6 000 lb., which would be necessary to obtain a correct comparison with Mr. Steinman's M-60 loading, the agreement between the two would be still more striking, as this would raise the equivalent E-ratings for the longer span lengths. Also, for shear, the agreement is nearly as close, the Cooper loading giving slightly higher shear stresses.

The author takes a span of 140 ft. as an example to show the deficiencies of the Cooper loading. He shows that, in the members of such a span, the Cooper loading would give stresses varying by as much as 37% from those produced by the N-1-S engines of the Pennsylvania Railroad Company. Such variations will always be found, some greater, some less, where actual locomotives are compared with a conventional set of wheel loads, whether such loadings are the Cooper or the proposed M-60 loading.

The Cooper E-loading was adopted for the A. R. E. A. 1920 Specifications for Steel Railway Bridges, after thorough discussion and consideration. Some of the reasons in favor of the retention of this loading have been given in a paper* by Mr. W. S. Bouton and the writer.

The writer can see nothing of practical value to be gained and much to be lost by changing from the Cooper to the proposed M-60 loading, or to any other loading yet devised.

Clement C. Williams,† M. Am. Soc. C. E. (by letter).‡—This able paper is a valuable contribution to the science of structural design and should promote economy, adequacy, and consistency in the design of railway bridges. Although the Cooper loadings were a boon to structural engineering in one sense, they have been a detriment in another, inasmuch as they have caused the Profession to be so satisfied with a good device as not to seek a better one.

The writer in classifying many existing railroad bridges according to the Cooper loadings has observed the inconsistency of design required by that system. Mr. Steinman's statement that an error of 20 to 37% results from expressing modern loadings in terms of the Cooper engines does not indicate the seriousness of the lack of balance in most designs, for to find a structure the chords of which would class as E-50 and the web or floor of which would class as about E-25 is common, notwithstanding that the structure is fairly satisfactory as to actual requirements.

The consolidation type of locomotive will probably never again be the prevailing type and, therefore, it represents, in its close concentration of load, a system of loadings different from those to which railway bridges will be subjected. Hence, there seems to be little excuse for continuing the inconsistent designs which result from this antiquated conventional loading. In fact, as long as it is continued, it will be common practice to remove old bridges because some of the main members and details are inadequate, while much of

* Am. Ry. Eng. Assoc. *Bulletin No. 219*, September, 1919.

† Univ. of Illinois, Urbana, Ill.

‡ Received by the Secretary, September 11th, 1922.

the structure is amply strong to carry the heavier loads to which it is subjected.

The Cooper system of loading has demonstrated the advantages of a conventional system of wheel loads as a basis of design for railway bridges, and probably the present need is a revision of the system rather than a radical departure in the type of loading.

The results obtained by the Special Committee on Stresses in Railroad Track reveal the effect of wheel concentrations in a new light and seem to call for accentuating this effect rather than minifying its importance by the use of equivalent uniform loads. Unless locomotive equalizers can be improved, it might be desirable to break the uniformity of axle loads and ascribe additional load to the main driving axle. In the writer's opinion, economy of design will be hindered rather than enhanced by the adoption of such an equivalent uniform load as that which the author proposes.

It is doubtful, however, whether a single system of wheel concentrations can be adopted, which will meet the varying needs. Cantilever structures for carrying locomotives need be designed frequently, for which close concentrations of wheel loads lead to grossly inaccurate results; therefore, the needs seem to require several different types of wheel concentrations, to be applied according to the anticipated development of locomotives as demanded by the topography and traffic conditions of the contiguous districts. One of these types certainly should be similar to that represented by the author's M-series, and the other extreme should be one of about two or three concentrations, as represented by the Atlantic type of locomotive, to be used especially for short spans, whereas the third might be an intermediate type similar to the Cooper engines. The development of locomotives in recent years has shown the Mallet locomotive as the logical type for heavy loads and steep grades, hence, the design of structures on such roads should be predicated on a locomotive loading of this type. The demands of topography and of traffic in so far as they affect locomotive types can be predicted with a fair degree of reliability and bridges should be designed accordingly.

Attention should be called to the desirability of considering the entire problem of loads and stresses together rather than separately. The question of loadings to be used is not more than half the case, for many of the present and past inconsistent or unbalanced designs are due to illogical selections of unit stresses quite as much as to illogical schemes of loading. Every one knows that 16 000 lb. per sq. in. does not represent the limiting safe working stress in steel in direct tension. There is little uncertainty about the strength of materials; the uncertainty lies in the loads to which the structure is subjected. The logic of the situation, therefore, would demand that the factor of safety be inserted in the loadings rather than in the unit stresses. This arrangement would make a consistent design as between dead and live load, which is not obtainable under most existing specifications. Indeed, this illogical situation permeates nearly all structural steel design—buildings as well as bridges. Specifications governing reinforced concrete design are decidedly in advance of those for steel in this respect.

Mr. Steinman has opened an important question and has made a valuable contribution, but the writer would urge that the entire question of loads and

stresses be considered together, because a simple change from the E-series to an M-series is not likely to afford a permanent improvement. When a custom or device has become so ingrained in the education of engineers through years of use as the Cooper loading, considerable professional inertia is to be expected when an improvement is proposed. It is to be hoped, however, that the author's valuable contribution will lead to the introduction of a system of loadings and stresses that will yield a more consistent and economical design for railway bridges.

Jonathan Jones,* M. Am. Soc. C. E. (by letter).†—The following assumptions underlie the author's method:

(1).—On any important railroad, the structures should be designed for the typical rolling stock of that or any other railroad, with a consistent factor of safety, rather than for the typical rolling stock of the home road, with a consistent factor of safety, but subject to certain over-stresses from rolling stock of other types.

(2).—As locomotive weights increase hereafter, they are likely to increase by the retention of present types and wheel-spacings, with a proportionate increase of each wheel load.

(3).—There is an advantage to be derived from having a uniform loading specification throughout the country.

If these assumptions hold, the author's work is so searching and instructive that it becomes authoritative, and his recommendations deserve to be put into force.

These were Cooper's assumptions also, and that they have not generally held is indicated by the number of railroads which use something other than the Cooper loadings, also by the discrepancies, pointed out by the author, between the heavy Cooper system and present-day developments.

Are the assumptions of to-day, then, better than former ones? The writer hopes that they will be thoroughly discussed by mechanical engineers; certainly, the whole matter must be referred to the American Railway Engineering Association before these assumptions can be disposed of.

Regarding Assumption (1), if the only negative argument was the present-day distinctions of railroad ownership, management, and design, one could foresee these distinctions breaking down, and rolling stock traveling promiscuously as it did during the World War. However, in locomotive types are there not districts, and, therefore, groups of railroads, which always will be well served by one type and poorly by another; so that if extra metal was placed in a certain truss member to accommodate this latter type at the normal unit stress, money would have been spent, that might well have been saved.

Regarding Assumption (2), will the development of electric traction introduce a type so different as to re-determine some of the author's maximums? Or, if the present types remain as the normal types, will they grow by mere proportionate increase in weight, or must not the wheel-bases increase? Will weight per foot of train, increase in proportion to locomotive weights? It

* Res. Mgr., McClintic-Marshall Products Co., Tatanagar, India.

† Received by the Secretary, September 13th, 1922.

seems to the writer that before any given railroad, well satisfied with the correspondence between its present designing stresses and the author's M-50, should specify M-50 plus an allowance for 50% overload, it might properly assume its present locomotive type, expanded both in weight and in dimensions, and compare the future stresses, thus calculated, with M-75 before accepting the latter.

With Assumption (3), the writer is in accord. Each step in bridge design from the preliminary estimate to the finished details would be simplified, cheapened, and increased in accuracy through the building up of standards of comparison, if more railroads would yield their special loadings and agree to a common standard. Therefore, the writer hopes that, even though the permanency of a new standard adopted to-day, may be voted dubious, one may be adopted, if only as a second step toward the ultimate—provided, that there is a pledge of adoption by sufficient additional railroads and an assurance of its persisting for, say, two decades more.

For the purposes of such a transition, a wheel-load diagram would be the least radical and the most acceptable. It is regrettable that the proposed M type differs from any existing type in the change of driver spacing and driver weight in the two groups. This will make it difficult to "sell" the type to literal minded executives whose reactions will be that it is like neither their own engines nor those of any other railroad, and, therefore, cannot be reasonable. The logical answer to this is found in the author's derivation of the type. Besides the advantages listed by the author, a diagram has the advantage, as a transition step, that it is a picture which invites review as mechanical developments come. The excess concentrations, or the formula proposed, if once adopted, lose all significance, except that they get a certain mathematical result. They are stopping, not starting, points in the reasoning, and until engineers are agreed that the starting point is beyond further revision, they should not bury it in a formula, but keep it out where everybody can look at it. This latter refers to the choice for publishing in a specification. The designer, however, would probably forget the wheel-load picture, paste Fig. 2* or Plate XVII† in his handbook, and perhaps memorize Formula (4)‡ for emergencies, feeling more than a little grateful to the author for precious hours of computation saved him thereafter.

GLENN B. WOODRUFF,§ ASSOC. M. AM. SOC. C. E. (by letter).‖—The author deserves the thanks of the Profession for the study he has given to this subject.

The Cooper system of loadings does not fit present-day conditions, and this divergence is likely to be increased by future developments in engine and train loadings. However, the Cooper system is in general use, and, before making a change, it would be well to take all possible measures in order that the changed loading will meet the developments of the next thirty years as well as the Cooper loading has done in the past. A thorough study of present and

* *Proceedings*, Am. Soc. C. E., May, 1922, p. 1053.

† *Loc. cit.*, p. 1059.

‡ *Loc. cit.*, p. 1065.

§ Asst. to Bridge Engr., Lehigh Val. R. R. Co., Bethlehem, Pa.

‖ Received by the Secretary, September 19th, 1922.

probable future developments of motive power and equipment design should be made by the proper committees of the Society and of the American Railway Engineering Association.

In considering the engines selected by the author as a basis for his "composite loading", the following suggestions are offered:

1.—One of the locomotives shown was built for pusher service and moves only over a limited part of the owning railroad. Others were built for roads having peculiar operating conditions. It is a question whether such locomotives are likely to come into general use.

2.—Engine No. 3 is probably somewhat ahead of its time, considering the present trend of locomotive loadings. The writer believes that the "composite loading" does not provide for short spans as it should and suggests adding a hypothetical engine of the Pacific type with axle loads of about 84 000 lb. on drivers. This would necessitate modifying the M-loading by specifying an alternate loading that would govern for short spans.

3.—Although the uniform load of 6 000 lb. may represent present-day conditions, the writer believes that it is not enough to be in keeping with the locomotives shown. There is probably more chance for a large increase in the train load than in the engine load. The writer would suggest an increase of about 10% in the train load of the proposed M-loading.

Considering the three alternate solutions proposed by the author, the writer prefers the continued use of the wheel loads. The saving of labor by the "simplified" methods is slight. By the use of tables and diagrams, the calculation of live load stresses is an easy task. It is a simple matter to prepare influence lines for any structure and then use the values given on Plate XVII.* Having a set of concentrated loads in mind, one is less likely to err when it is necessary to give a hurried ruling on the acceptance or refusal of a heavy shipment.

The divergence between the "simplified" loadings and the "composite loadings" are nearly as great as between the composite loadings and the Cooper E-65. The writer fails to see any valid argument in favor of their use. Instead of designing for the M-60 loading with a provision for 25% overload, the writer suggests designing directly for M-75, both for simplicity and economy. For economy of metal, it is desirable that all members should reach their limit under the same load, and the logical method of securing this result is by designing for ultimate load.

T. Kennard Thomson,† M. Am. Soc. C. E. (by letter).‡—The author deserves the thanks of the Society and the Profession for his valuable contribution on engine loadings. The writer recalls the unnecessary labor due to the great variation of loads, not only as specified by different roads, but also as adopted by individual roads. When he began working for a bridge company about thirty-six years ago, the entire design of bridges was in the transition period. Not only did each railroad have its own engine diagrams, but it also had its

* *Proceedings*, Am. Soc. C. E., May, 1922, p. 1059.

† Cons. Engr., New York City.

‡ Received by the Secretary, September 22d, 1922.

own peculiarity of design. Designs were so different that a glance would enable one to tell the railroad for which a shop plan was being made. The same applied to the bridge companies, as one would know, in most cases, on seeing a completed bridge, what company had built it.

In the intervening years, however, the railroads and the bridge companies have adopted the best and have discarded the poorer features, so that there is now much more uniformity. Probably no single feature has changed more than the engine and train loads. The efforts of each railroad to design its bridges as close as possible to one or two types of engines, has, in many cases, been false economy.

If Mr. Steinman's valuable paper causes the adoption of a few standard engine load diagrams much mechanical labor in estimating will be saved, and the result will probably be fewer errors, more uniformity of design, and much less likelihood of frequent replacement.

As engineers, other officials, and even owners of railroads are changed so often, and as the same freight transfers from one road to another, it seems absurd to have such an infinite variety of engine loads adopted, only to be superseded by others in a few years.

The late Theodore Cooper, M. Am. Soc. C. E., was probably the first to devise an engine diagram which was generally adopted. The highway bridge companies often simplified matters by specifying a uniform load, plus a concentrated load, which saved much labor.

The writer hopes that Mr. Steinman's paper will result in the adoption of a few standard systems of loading, which will be tabulated for a uniform load per linear foot, and that these loadings will include long-span bridges for highway, combined highway, and railway purposes.

C. R. Young,* Assoc. M. Am. Soc. C. E. (by letter).†—The author is to be congratulated for the service he has rendered the Engineering Profession in placing before it, data so convincing as to leave no other course open than to revise the present obsolete locomotive loadings. Much discussion has been given, in recent years, to the alleged inapplicability of the Cooper system of conventional loadings, but in most cases this has been of a desultory and general character. The author has established that, for heavy loadings on first-class railway systems, the Cooper system is inadequate and that the new proposed system would give safe and logical results. It now remains for the railway systems to make the next move. It is to be hoped that this will not be long delayed, and that, in particular, the American Railway Engineering Association will reconsider its decision to abide by the Cooper system.

Caution is needed in attempting to apply the author's proposed system of loading to railways carrying only moderately heavy traffic. Although his loadings are admirably suited to the heavier lines operating with steam locomotives, they are not so closely applicable to average or second-class lines on which existing locomotives, and those likely to be used for some years to come, are of a type distinctly different from those used by Mr. Steinman in the establish-

* Assoc. Prof. of Structural Eng., Univ. of Toronto, Toronto, Ont., Canada.

† Received by the Secretary, September 23d, 1922.

ment of his composite loading. For this reason, it may be preferable to retain on some railways a loading system that more closely approximates the actual loadings in use than any class of the author's standard loading. The electric locomotive is becoming important and should be considered in any system that is devised to be used for a long time.

Of the three types of loading proposed, the writer prefers the loading formula. As each of these loadings is empirical, there seems to be no good reason to halt part way in the determination of stresses in bridge structures. Rather than adopt a loading that is conventional, it would seem best directly to adopt stresses that are conventional. There is no greater offense in the second method than in the first. It may be desirable to retain the wheel loading for investigation of special parts of structures receiving their maximum stresses under short loading, but, in most cases, the writer believes a distinct advantage would be derived from proceeding directly to the use of the loading formula.

EDWARD GODFREY,* M. AM. SOC. C. E. (by letter).†—The author's able paper clearly demonstrates that, for the heaviest type of locomotive, coupled to the heaviest loads usually carried, the Cooper loading does not give consistent stresses nor economic design. This is, however, not a conclusive reason for discarding the Cooper standard of loading. If all bridges could be rebuilt, it would be desirable to establish a standard of loading to correspond with the latest in modern engine construction. Bridge specifications, however, are used largely to judge the capacity of existing bridges as well as a standard by which to build new ones. Furthermore, perhaps, a large mileage of the railroads in the United States will never be called on to carry the very heavy engine loads that are in use on a few of the roads. It would mean the rebuilding of many bridges and even the laying of heavier rails to enable these roads to carry heavy loads. As a criterion for judging the bridges on such roads or the building of new ones, these heavy loads, therefore, are just as inappropriate as the Cooper loading is on roads where the modern heavy engines are in use.

It is difficult to discard a system of calculating stresses that is as interwoven with railroad bridge design as the Cooper standard loading. By using two simple modifications of the Cooper standard of loading the author's principal objections can be overcome, and it can be made to give results as nearly equivalent to the modern heavy loading as practical considerations demand.

One modification is to use heavier axle loads in the pair of concentrations for stringers or short girder spans. The other modification is to use a train load less than that called for by the class of engine in the standard. For example, let an E-70 engine be followed by 6 000 lb. per ft. instead of 7 000 lb. per ft. By a simple rule such as this, the lack of economy in long spans is eliminated.

* Structural Engr., Robert W. Hunt & Co., Pittsburgh, Pa.

† Received by the Secretary, September 29th, 1922.

After a standard of design is once established, it should be adhered to with little or no departure. One can believe this and still be aware of the fact that the exact stresses computed may never be even closely approximated in the bridge. The ends of safety and stability are served, and this is the principal object. The main reason for rigid adherence to certain rules in calculating stresses is to have a definite standard of design. In competitive design, this is particularly useful, as without a definite standard, comparisons could not be made. It is not so necessary, therefore, whether a diagram of loading agrees exactly with the axle loads of a locomotive, as long as the heavy concentrations in the diagram practically agree with those to be used, or as long, in fact, as the load per foot is almost the same.

The only bridge loading for calculating stresses that can be tolerated by designers is either a uniform load, a system of concentrations, or a combination of both. To introduce a new system of concentrated loads would place a great burden on designers who are familiar with the Cooper loading and have many tables, etc., based on it.

It would not be wise to mask bridge loading by a formula, as proposed by Mr. Steinman. The general manager of the railroad will say, "never mind the formula, what kind of engine and train loading can I run over this bridge?"

To try to interpret the strength of an old bridge, or a new one for light loads (and such will be built for many years to come), with respect to the heavy Mallet type of loading, would be just as awkward as it is to interpret the strength of a heavy bridge by the use of the Cooper loading.

The Cooper loading standard is needed and can be used for many years to come, and with slight modifications it can be made to suit any modified locomotive loading with all the accuracy that actual conditions demand.

A. F. Robinson,* M. Am. Soc. C. E. (by letter).†—The author has condemned the E-loadings and submitted a new loading. In the writer's judgment, the Cooper loading is superior in every way to that proposed by the author. The simple statement in the paper that the Cooper loading is out of date does not necessarily make it so. The author has submitted nothing whatever, except this bare statement.

Before adopting the Cooper E-loading, when making up the A. R. E. A. specifications of 1920, Committee 15 of that organization studied the question with extreme care. A sub-committee submitted a report which showed that the moments and shears for the E-series loadings compared with those for all the heavy engine loadings.

In the writer's opinion, it is not necessary to try to make up an ideal engine loading which shall consider in any way the Mallet type of locomotive, as it will not be necessary to provide for many engines of that type. Experience has demonstrated that the large Santa Fé type and the Mikado type of locomotives will give much better net returns in service than any of the Mallet types. This being the case, there is no need of providing especially for the Mallet engines. As locomotive designing progresses, it may be neces-

* Bridge Engr. System, A. T. & S. F. Ry., Chicago, Ill.

† Received by the Secretary, September 30th, 1922.

sary to modify or re-construct the E-loadings, but it is not necessary for the present and the immediate future. A careful study of the report of Committee 15 of the A. R. E. A., submitted with the 1920 specifications of that organization, will clearly demonstrate what the writer has stated.

The E-loadings follow very closely the weights, moments, and shears, as given by the heavy power in service, which includes the Mallet type of engines. This E-loading furnishes a unit or basis for comparison which has been generally adopted. The locomotive loading proposed by the author is in advance of anything that is likely to be used on the Atchison, Topeka and Santa Fé Railway for many years to come. An engine loading that is materially in advance of the engines that are being used at the time, should not be adopted.

Although the E-loading can be criticized in many ways, it still meets present-day requirements very well and is much to be preferred to the loading submitted by the author. The M-60 loading does not give any check on the effects of the motive power now in service. Before this system of loading is generally used, the locomotives must increase materially in weight and a different kind of a roadbed, together with much heavier rails, will be necessary. The writer is in favor of adhering to the E-loadings. This is a case where the cure is much worse than the disease.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

TESTS OF CONCRETE IN SEA WATER

Technical Papers Presented at the Annual Convention, Portsmouth, N. H., June 21st, 1922

Discussion*

By Messrs. A. H. Rhett and L. F. Bellinger.

A. H. Rhett,† Assoc. M. Am. Soc. C. E. (by letter).‡—The fact is now established that concrete in contact with sea water undergoes disintegration under certain conditions, and the test conducted by the Aberthaw Construction Company, a final report on which has been made by Mr. Wason,§ has done much to establish this fact. Opinions seem to differ as to the cause of this disintegration, but the writer believes that the results of the various tests and examinations indicate the cause quite definitely.

It has been stated‖ that:

"Hydraulic cement is readily decomposed if intimately exposed to the chemical action of various sulphate and chloride solutions as contained in saline and alkaline waters, if the solutions are of sufficient strength, * * *. The cause of this disintegration is not certain, though it is almost universally believed that it is the reaction of the sulphate of magnesium of the sea water with the lime of the cement (formed during setting)."

It is also stated in that paper that: "The most soluble element of the cement is lime," and that the action is more vigorous in set cements than in unset cements because, "in set cements a considerable part of the lime has been already hydrated." And, further, that "contrary to the opinion of the many, there is no apparent relation between the chemical composition of a cement and the rapidity with which it re-acts with sea water."

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* Continued from September, 1922, *Proceedings*.

† Gen. Sales Mgr. and Engr., Toch Brothers, New York City.

‡ Received by the Secretary, September 12th, 1922.

§ *Proceedings*, Am. Soc. C. E., September, 1922, p. 1597.

‖ "Action of the Salts in Alkali Water and Sea Water on Cements," U. S. Bureau of Standards, *Technologic Paper No. 12*.

The Aberthaw test confirms the statements just mentioned in demonstrating that the specimen to which hydrated lime had been added, showed very active disintegration. These findings have been confirmed by other investigators and seem to establish the fact that the disintegration of concrete by sea water is caused by the reaction of the sulphate and chloride solutions of the water with the free lime (formed during setting) present in the concrete. Investigation has further disclosed that disintegration occurs principally where the concrete is alternately wet and dry, as between the high and low-water marks. In some cases, however, even under these conditions, disintegration does not occur. The question arising then is: If concrete contains lime, which is disastrously affected by ingredients in sea water, why does disintegration occur chiefly where the concrete is alternately wet and dry, and, even then, does not always occur. The answer can be summed up in one word—porosity.

It would seem that sea water is not sufficiently strong in the sulphate and chloride solution to start this chemical action. If, however, the concrete is porous, each flushing fills the pores, and each drying out leaves a minute deposit of the salts. This process, repeated indefinitely, eventually produces a sufficiently concentrated solution in the pores to produce the chemical reaction and accompanying crystallization which disrupts the concrete. This action has been found to penetrate deep into the concrete—as much as 4 or 5 ft. It should be clear, then, that if concrete can be made non-porous, it will not be subject to this action of concentrated solutions and, therefore, will be stable in sea water.

L. F. Bellinger,* M. Am. Soc. C. E. (by letter)†.—The U. S. Bureau of Standards has investigated the action of sea water on concrete structures, and the report of Messrs. Wig and Ferguson on this subject has been published by the Bureau of Yards and Docks of the Navy Department,‡ in which reference is made to the various concrete quay walls in the Brooklyn Navy Yard, that were built at various times during the last thirty years. Pertinent extracts from the report are, as follows:

"The condition of the structures built between 1901 and 1904 is in striking contrast with those built prior to this period. * * * None of these walls has been repaired and, with one exception, the wall at berth 17-*h*, none is appreciably deteriorated."

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"Much of the repair work and replacement work which was carried on subsequent to 1912 has deteriorated to a considerable extent. In some cases, as at wall berth 1-*a*, rebuilt in 1913, the repair work is in need of extensive repairs now."

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"There are defects 'in the case of the reinforced concrete in Piers *E* and *F*, in which the cracking of the concrete is due to the corrosion of the embedded reinforcement which is uncoated and not embedded to a sufficient depth.' "

* Lt.-Commander, C. E. C., U. S. N.; Public Works Officer, U. S. Naval Submarine Base, New London, Conn.

† Received by the Secretary, September 21st, 1922.

‡ *Bulletin No. 28*, October, 1917.

The report shows that the structures built during the period, 1901-04, are better than any built before or since, in that Navy Yard. After fifteen years, no repairs were necessary to such structures, whereas, after three years, extensive repairs were needed in a quay wall that was rebuilt in 1913. It appears desirable, therefore, to examine in detail the conditions that provided a concrete quay wall on which no repairs were needed after thirteen years, particularly as to the plasticity or workability of the concrete mixture and the workmanship required in placing it.

The materials were ordinary, high-grade aggregate and cement, secured about New York City on competitive bids. In his paper,* Mr. Wason shows well the effect of too little water in concrete for use in sea water. Numerous laboratory experiments at various universities show the great deteriorating effects of too much water in concrete in any location. Both too much and too little water are dangerous, because when concrete is too dry or too wet it is more easily mixed than when it is "just right". A description of what is "just right", as determined by long experience, is the purpose of this discussion.

Messrs. Wig and Ferguson describe the sea-wall concrete as being "plastic". That term is very good, but, in the West, the equivalent term is "ankle-deep concrete", and, in the East, the term, "quaking mixture", is used. Neither term is quite correct for describing physically that quality of the concrete placed in the Brooklyn Navy Yard in 1901-03. This concrete was a 1 : 2 : 4 mix that was turned three times on the mixing-board, shoveled into wheelbarrows, dumped into the forms, and rammed into place. A light ramming produced a jelly-like mass, into which the workmen's feet would sink from 1 in. to 2 in. The mortar facing was a 1: 2 composition, placed by shovel next to the forms as concrete was placed directly back of it, thus securing a facing 2 in. thick integral with the concrete, but no precision was attempted on any plane of demarcation between the facing and the concrete. The degree of plasticity of the mortar was the same as that of the concrete. From the foregoing, it may be seen that less ramming was used than would have been necessary with a "quaking" mixture and, therefore, a little more water was used; also, that appreciably less water was used than in the Western "ankle-deep" concrete. Frequently, the tide rose over the soft concrete within 15 to 30 min. after it had been placed in the forms.

In 1895, the writer began the mixing of "concrete medium" with the disapproval and scorn of contractors and foremen. The explanation given then, was that a certain quantity of water was necessary for the concrete properly to "set"; that less than that quantity would result in a weaker, more porous concrete; and that a slight excess of water would, by heavy ramming which was then the practice, force surplus water to the surface where it would either run off or evaporate. Although it was then considered as an unsound practice, it was insisted to be far better to have too much water than too little

The first opportunity for mixing concrete "exactly right", was at the Brooklyn Navy Yard, in March, 1901. This "sticky" concrete was more difficult to handle than the dryer mixture and close inspection was necessary

* *Proceedings*, Am. Soc. C. E., September, 1922, p. 1597.

to secure concrete approximating closely the "exactly right" plasticity, because extra labor was required and this causes friction. Nevertheless, results were obtained, that proved the great economy in repairs which is mentioned in the report of the Bureau of Standards.

The writer concurs in the conclusions of Mr. Wason regarding concrete for use in sea water. When the moisture freezes and swells, a grain of sand or a pebble is forced out of place. Deterioration proceeds slowly in a mortar facing 2 in. thick as compared with the rate when the concrete itself is exposed to the freezing and thawing process.

The Standard Cement Specifications of the Navy Department have provided ample protection against chemical action. Abrasion from floating ice and from wave action is certain to occur. It will progress more rapidly in the concrete than in the mortar facing, because larger particles will be removed. Mortar facing from low tide to high tide should be thicker than in other parts of the wall, and some facing should extend to the top of the wall and across the coping, unless a stone coping is used.

The record of these particular quay walls and of recent laboratory tests have proved that the quantity of water used in mixing is of the greatest importance. The kind of water is of little importance; in some of the walls, fresh water was used for mixing, but in most of them East River water was used.

Failures in some seaside concrete structures and in the Boston Navy Yard samples show well what not to do. Sloppy concrete and dry concrete are thereby proved to be taboo. This discussion is written with the desire to assist in showing what to do to secure the most durable concrete in sea water.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

TENTATIVE SPECIFICATIONS FOR CONCRETE AND REINFORCED CONCRETE

SUBMITTED AS A PROGRESS REPORT OF THE JOINT COMMITTEE ON STANDARD SPECIFICATIONS FOR CONCRETE AND REINFORCED CONCRETE

Discussion*

By MESSRS. JACOB FELD AND C. S. WHITNEY.

JACOB FELD,† JUN. AM. SOC. C. E. (by letter).‡—In reference to Sections 78 and 79, on "Waterproofing",§ the writer desires to submit the results of some experiments on the "porosity of concrete" performed at the University of Cincinnati during 1920.

The apparatus consisted of two heavy steel plates, through each of which was a 5-in. hole. The two plates could be bolted together so that the holes would be in alignment. Between the plates was placed a concrete specimen, 6 in. in diameter and 2 in. high, cast in a sheet-metal mould so that on one circular face the edge of the metal projected about 1/8 in. A flat rubber ring was placed around the edge of the specimen, providing a water seal after the specimen had been clamped. A cap was then screwed into the hole of the upper plate, which cap was connected by a 3/8-in. pipe to a closed tank, containing about 20 gal. of water. One face of the specimen was subjected to water, under pressure, by admitting compressed air into the tank. It had been planned to maintain sufficient pressure to force water through the 2 in. of concrete, but a few tests showed this to be impractical. The specimens were stored in water for 28 days before testing.

The figures given in Table 12 are reproduced from some notes taken by the writer from the students' reports, and are merely a summary. The two

* Continued from August, 1922, *Proceedings.*

† Brooklyn, N. Y.

‡ Received by the Secretary, September 5th, 1922.

§ *Proceedings,* Am. Soc. C. E., August, 1921, p. 82.

sets of tests were performed independently, different aggregates being used, the cement being the same kind in each case. Each set covers ten different water-proofing methods. The specimen was weighed as soon as it was removed from the water bath (and its surfaces blotted), and then subjected to water under a pressure of 40 lb. per sq. in. for 2 hours. After blotting again, the increase in weight was taken as the weight of water absorbed. The average specimen weighed about 2 300 grammes.

TABLE 12.—TESTS ON 1 : 2 : 4 CONCRETE.

Test no.	SET I, BANK SAND AND GRAVEL.	SET II, RIVER SAND AND GRAVEL.	Water-proofing materials
	Grammes of water absorbed.		
1	96	85	None. 1 : 2 : 4 mixed dry.
2	63	71	Lime. 5% of cement by weight.
3	54	44	Clay. 5% of cement by weight.
4	37	43	Thick application of lye soap.
5	48	40	Oil. 10% of the normal water.
6	46	56	Medusa. 0.02% of concrete by weight
7	31	40	None. Wet mix; cement came to surface.
8	40	30	Ceresit. Directions followed.
9	30	35	Thick application of alum.
10	15	25	½ in. of neat cement cover on 1½ in. of concrete.

Although the writer claims no great accuracy for these tests, the agreement between the two sets permits some conclusions to be drawn. Undoubtedly, the best water-proofing material is a neat cement surface. All the materials used were beneficial, reducing the quantity of water absorbed. The wet mix caused the cement to form a thin surface layer; this was true only because the specimen was cast in the same position that it was used. The thick applications of soap and of alum acted as membranes. In trying to force water through a specimen, a 1 : 2 : 4 untreated mix (Test No. 1) was left under a pressure of more than 40 lb. per sq. in. for 6 hours, without any perceptible water appearing on the lower surface.

C. S. WHITNEY,* ASSOC. M. AM. SOC. C. E. (by letter).†—This report of the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete recognizes more fully than did the former Joint Committee report‡ the strength of spiraled columns and the weakness of columns reinforced with widely spaced ties. The correctness of this principle will be generally conceded.

The form of Formula (43),§ $P = A_c f_c + n f_c\, pA$, is the same as that given in the previous Joint Committee report, but when f_c is given as a variable, depending on the percentage of vertical steel ($f_c = 300 + (0.10 + 4p)\, f'_c$), the formula takes a new form which is different from all the many formulas now in use. This new form cannot be expected to replace all other forms, unless it is strongly recommended by proved facts.

* Cons. Engr., Milwaukee, Wis.

† Received by the Secretary, September 7th, 1922.

‡ *Transactions*, Am. Soc. C. E., Vol. LXXXI (1917), p. 1101.

§ *Proceedings*, Am. Soc. C. E., August, 1921, p. 102.

In connection with this new formula, the provision is made that the spiral reinforcement shall not be less in amount than one-fourth of the volume of the longitudinal reinforcement. The formula provides that, as the percentages of longitudinal and spiral reinforcement increase, the allowable unit stress shall increase, but it does not provide for an increase in unit stress when the spiral reinforcement only is increased.

Tests do not indicate that this increase in allowable unit stress is justified by the presence of more longitudinal reinforcement. The increased strength must be due to the heavier spiral, yet in the proposed formula the unit stress is a function of the percentage of longitudinal reinforcement only. For the assumed ratio of spiral to longitudinal steel, the values given by the proposed formula may be satisfactory, but unless it can be demonstrated that in all cases the amount of spiral reinforcement should be one-fourth of the longitudinal steel, the formula is not complete and should not be accepted as final.

In designing a reinforced concrete structure, it is generally advantageous to keep the size of the columns as uniform as possible and vary the reinforcement with the load to be carried. In such a case, with uniform column size, it is not desirable to vary the spiral with each variation of the vertical reinforcement, and the proposed formula is obviously not suited for use when the spiral is constant and the vertical steel varies. The formula should be of such a form that it would be possible to assume the percentage of spiral reinforcement and vary the amount of vertical steel.

The other point which the writer wishes to emphasize, is that, as given, the formula requires unnecessary labor for its application. An increase in economy or efficiency in the structure being designed will justify much additional labor, but in this case substantially the same results can be obtained much more easily.

When the constants for 2 000-lb. concrete are substituted in the proposed formula, it reduces to the following:

$$P = 500A \ (1 + 30p + 224\,p^2)$$

involving both the first and second powers of the percentage of longitudinal steel. The straight-line formula

$$P = f_c\,A + (n-1)\,f_c\,A_s$$

can be made to correspond very closely with the proposed formula, if the proper values of the constants are chosen. For 2 000-lb. concrete, this corresponding straight-line formula reduces to:

$$P = 450A + 21\,000A_s.$$

The results given by the quadratic and the straight-line formulas are so nearly alike that it would be absurd to state that the present knowledge of the strength of reinforced concrete columns could justify the use of the more involved formula instead of the simpler one. In fact, when the formulas are plotted together, the straight-line formula might seem to be the more logical, because it does not seem proper that a given increment in vertical reinforcement should produce a greater increase in strength in a column with 5% of vertical steel than it will in one with less reinforcement.

In view of these facts, the writer would strongly recommend the adoption, if possible, of a straight-line formula similar to that given in the former Joint Committee report.* It can be made to agree with the results of tests as closely as any other form. In designing a large number of columns for a building, the first considerations are the size of the columns and the continuity of the vertical reinforcing bars. Whatever its derivation may be, the formula, therefore, should reduce to the form:

$$P = C_1 A + C_2 A_s$$

in which the constants, C_1 and C_2, may be made to depend on the strength of the concrete and the amount of spiral reinforcement. The strength of the concrete and the amount of spiral reinforcement will then be assumed in advance of the design of the columns, and the actual spirals can be selected after the longitudinal steel is selected.

* *Transactions*, Am. Soc. C. E., Vol. LXXXI (1917), p. 1152.

MEMOIRS OF DECEASED MEMBERS

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

WILLIAM HASELL WILSON, Hon. M. Am. Soc. C. E.*

DIED AUGUST 17TH, 1902.

William Hasell Wilson, the son of John and Eliza (Gibbes) Wilson, was born at Charleston, S. C., on November 5th, 1811. His grandfather was an Engineer and served as a British officer during the Revolutionary War. His father was also an Engineer and Surveyor, and served the United States as an Engineer Officer during the War of 1812. It is interesting to note that Mr. Wilson's grandfather planned the British attack on Charleston, S. C., and Savannah, Ga., during the Revolutionary War, while his father planned the American defense of those cities in the War of 1812.

Mr. Wilson received his education at Charleston, S. C., Morristown, N. J., and Philadelphia, Pa., where he entered the High School of the Franklin Institute. In June, 1827, he joined an Engineer Corps which his father had organized under the direction of the State of Pennsylvania, for canal and railroad surveys through Chester and Lancaster Counties. When this work was completed, he continued his studies, concentrating on drawing and mathematics.

In March, 1828, Mr. Wilson was employed as Rodman with a corps of engineers engaged in locating the Philadelphia and Columbia Railroad. In 1829, he became Assistant Engineer in charge of the construction of twenty miles of road in the Eastern Section, and held that position until April, 1831, when he was promoted to that of Principal Assistant Engineer in charge of construction of the entire Eastern Section, consisting of forty miles. The road was completed in October, 1834, and for a few years following, he was engaged in engineering work of a varied character.

In August, 1838, Mr. Wilson was appointed by the State of Pennsylvania as Chief Engineer of the Gettysburg Extension which was designed to connect the Philadelphia and Columbia Railroad with the Baltimore and Ohio Railroad. On the discontinuance of this work, in 1839, he returned to Philadelphia, and in February of that year he attended a meeting at Baltimore, Md., composed of engineers interested in organizing an engineering society. Plans were discussed, but it was finally decided that conditions were not then favorable for the success of the project, and the matter was dropped.

In 1839, Mr. Wilson was employed in making surveys for a proposed line from Downingtown to Reading, Pa., and also as Principal Assistant Engineer for the Philadelphia and Reading Railroad Company in the final location and construction of the Second Division of its road from near Pottstown to Bridgeport, Pa. The construction of the Black Rock Tunnel at Phœnixville,

* Memoir compiled from information furnished by Henry W. Wilson, M. Am. Soc. C. E., and on file at the Headquarters of the Society.

Pa., the entire length of which was excavated through solid rock, is a noteworthy part of this work. By the light of lanterns and candles, Mr. Wilson gave the instrumental work on this tunnel his personal attention. The excavation was made from both ends of the tunnel and through five shafts located at its edge, and when it was finished, the variation in alignment and grade did not exceed more than 0.01 ft. The fact that this work was undertaken sixty years ago, at a time when there was a dearth of geological data and construction tools, makes its successful completion very remarkable and worthy of note.

Owing to depressed business conditions, Mr. Wilson became engaged in farming and pursued this work with much zeal and interest from 1841 to 1852. Returning to the practice of his profession, he made surveys, during the summers of 1852 and 1853, for the Pennsylvania Railroad Company, and located a line from Philadelphia, *via* Phœnixville and the French Creek and Connestoga Valleys, to a point on the Harrisburg and Lancaster Railroad, about eight miles west of Lancaster, Pa.

In 1854 and 1855, Mr. Wilson served as Chief Engineer of the West Chester and Philadelphia Railroad Company. In January, 1856, he entered the service of the Pennsylvania Railroad Company, and made a survey for a railroad between the Delaware and Schuylkill Rivers through the southern part of Philadelphia. He also investigated railroad matters in the States of Ohio, Indiana, and Illinois, in the interest of the Company.

In August, 1857, he was appointed as Resident Engineer of the Philadelphia and Columbia Railroad, which had been purchased by the Pennsylvania Railroad Company. He reconstructed a large part of this road, making many changes, among which was the relaying of 6 350 ft. of south track west of Dillerville, Pa., with entirely new rail, the last of the edge-rail track laid in 1834.

Mr. Wilson's jurisdiction as Resident Engineer was gradually extended, first to Mifflin, Pa., and by January, 1859, it included the entire line and branches between Philadelphia and Pittsburgh, Pa., with headquarters at Altoona, Pa. In 1862, his title was changed to that of Chief Engineer, and he was assisted by an Engineer of Bridges and Buildings and a Resident Engineer, on each of the Philadelphia, Middle, and Pittsburgh Divisions.

During the Civil War, Mr. Wilson was engaged in frequent consultation with the State and Federal civil and military authorities, to whom he gave able assistance on railroad matters of vital importance. The road being of strategic value, his was a position of great responsibility at this time.

In January, 1868, following a re-organization of his Department, which was necessitated by increased pressure of work, Mr. Wilson was made Chief Engineer of Construction with headquarters at Philadelphia, where he was occupied in improving the various facilities of the Company, to provide for its growing business.

In November, 1873, he was elected President of the Philadelphia and Erie Railroad Company, at the same time continuing to act as Consulting Engineer of the Pennsylvania Railroad Company. In 1874, having been placed in charge of the Real Estate Department of the Pennsylvania Railroad Company, Mr. Wilson resigned his position as President of the Phila-

delphia and Erie Railroad Company. He was engaged in arranging and systematizing the work of that Department until his resignation in March, 1884, when he was again elected President of the Philadelphia and Erie, the Belvidere-Delaware, the Philadelphia and Trenton, and other railroad companies controlled by the Pennsylvania Company.

In 1894, Mr. Wilson resigned all these positions except that of the Presidency of the Belvidere-Delaware Railroad and its subsidiary companies, which position he held until his death on August 17th, 1902.

He was married on April 26th, 1836, to Jane Miller, of Delaware County, Pennsylvania, who died on May 11th, 1898. He was survived by five children.

It has been said of him that "always kind, charitable, and loving—a splendid type of the Christian man of science—his death, like his life, was beautiful, * * *. His work from the Delaware to the Ohio has left a lasting impression on the Commonwealth, and will remain as a monument to his abilities".

Mr. Wilson was elected an Honorary Member of the American Society of Civil Engineers on August 2d, 1892. He was also an Honorary Member of the Engineers' Club of Philadelphia.

GEORGE RUSSELL FIELD, M. Am. Soc. C. E.*

Died May 1st, 1922.

George Russell Field, the son of Elisha J. and Martha Woodbury Field, was born at Groton, N. Y., on October 1st, 1871, and received his early education in the public schools of that place. He attended Cornell University, but was not graduated on account of severe illness.

In 1889, Mr. Field entered the Engineering Department of the Groton Bridge and Manufacturing Company, and remained with that firm for nearly five years. He served in the Drafting Room for a year and a half, making shop details and checking drawings. He was then placed in charge of design and contracting for bridge and structural work, and he also had charge of erection in the field. For about a year, he acted as Contracting Agent for the Bridge Company in New York, Pennsylvania, and New Jersey. In May, 1893, he was transferred to San Francisco, Calif., where he represented the Company as Contracting Agent until January, 1905.

On the latter date, Mr. Field became Contracting Engineer for the Risdon Iron and Locomotive Works in San Francisco and continued with that firm in that capacity until 1910. His position with the Risdon Company covered various works, among which may be mentioned the structural steel for the Ferry Depot, San Francisco, and for the Spreckels Sugar Refinery, at Salinas, Calif. His principal work, however, was in connection with the construction and installation of pressure pipe lines and gates for hydro-electric power plants, among which may be named the three plants of the Edison Electric Company of Los Angeles, Calif., the Northern California Power Company, the

* Memoir prepared by J. D. Galloway, M. Am. Soc. C. E.

Puget Sound Power Company, and the Stanislaus Power Company of California.

In 1910, Mr. Field became Assistant General Manager of the Great Western Power Company, and served in that capacity until 1912. His duties with the Power Company were largely concerned with operation.

In 1912, he became interested in the Klamath River Packers' Association, and the following year he was made Vice-President and General Manager of the Company, a position which he held for nine years, until his death. In his capacity as General Manager, Mr. Field made a complete study of fish packing and re-organized the conduct of that industry for his Company.

His death on May 1st, 1922, in Los Angeles, where he had gone for a visit, was due to an attack of influenza in 1919, from which he had never completely recovered.

Mr. Field was married on January 28th, 1904, in San Francisco, to Miss Gertrude White McCauley, who, with his father, Mr. Elisha J. Field, survives him.

Mr. Field was a kindly, courteous gentleman, and to those who knew him well, the announcement of his sudden death brought a deep sense of sorrow and loss.

He was a member of the Bohemian Club of San Francisco and the Claremont Country Club of Oakland, Calif.

Mr. Field was elected a Member of the American Society of Civil Engineers on November 6th, 1907.

WALTER LAWRENCE HULL, Assoc. M. Am. Soc. C. E.*

Died June 20th, 1922.

Walter Lawrence Hull, the son of Edward Fred and Hattie Louise Hull, was born at Ossining, N. Y., on April 19th, 1885. He was educated in the Public Schools of Brooklyn, N. Y., and finished his schooling at Cooper Union, New York City.

In 1902, Mr. Hull commenced the practice of his profession as a Draftsman in the City Surveyor's Office, Brooklyn, N. Y. Subsequently, for a period of about six years, he served in various engineering capacities for the Lehigh Valley Railroad Company, in New York City; the Public Service Railway Company of New Jersey, in Newark, N. J.; the New York Central and Hudson River Railroad Company, in Yonkers, N. Y.; the Pennsylvania Railroad Company, on the North River Tunnels, in New York City; with Mr. Charles Cranford, Contractor, in Brooklyn; and with the Hudson and Manhattan Railroad Company, on tunnel work, in New York City.

In 1908, Mr. Hull entered the service of the Delaware, Lackawanna and Western Railroad Company, in the Engineering Department, and continued in the employ of that Company for about eleven years, except during 1910 and 1911, which he devoted to private practice in water-proofing work. During the

* Memoir prepared by William H. Speirs, Esq., Glen Ridge, N. J.

greater part of his service with the Delaware, Lackawanna and Western Railroad Company, Mr. Hull specialized in construction, his last work having been as Resident Engineer on the elimination of grade crossings at Passaic, N. J. Mr. Hull's ability was well adapted to construction work which reflected his well developed esthetic side, and his originality and progressiveness often resulted in the adoption by the Company of novelties in design and methods of construction which proved to be valuable.

Mr. Hull's achievements on track elevation through Orange, N. J., for the Delaware, Lackawanna and Western Railroad Company, on which he was engaged previous to his work at Passaic, N. J., resulted in his appointment as City Engineer of Orange in 1919, which position he held at the time of his sudden death on June 20th, 1922, from spinal meningitis, after an illness of only two days.

In 1906, Mr. Hull was married to Florence Irene Erwood, of Brooklyn, N. Y., who, with two sons and one daughter, survives him.

He was a member of Corinthian Lodge, F. and A. M., of Orange, N. J., the New England Society of Orange, N. J., and the American Road Builders Association.

Mr. Hull was elected an Associate Member of the American Society of Civil Engineers on January 19th, 1920.

JOHN ALEXANDER DAILEY, Affiliate, Am. Soc. C. E.*

Died February 9th, 1922

John Alexander Dailey, the son of Nicholas A. Dailey, was born in Kensington, London, England, on August 13th, 1839. His parents came to the United States when he was nine years old, and settled in Covington, Ky., where he was educated.

At the outbreak of the Civil War, Mr. Dailey who was located at Evansville, Ind., enlisted (April 19th, 1861) in Company E, 14th Indiana Infantry. He served with this regiment for 3 years and 3 months, and fought in the battles at Green Bar, Second Bull Run, Winchester, Antietam, and Chancellorsville. He was taken prisoner by the Confederates, but was afterward paroled and honorably discharged in 1864.

From 1865 to 1872, Mr. Dailey was employed with Mr. R. C. Phillips, Surveyor and Civil Engineer, of Cincinnati, Ohio, and from 1872 to 1880, he was engaged in the Engineering Department of the Cincinnati Southern Railway Company.

Mr. Dailey then went West, and from April, 1880, until his retirement in 1904, he was connected with the Atchison, Topeka and Santa Fé Railway Company in various capacities. During the early construction of the Company's lines, he served under the late A. A. Robinson, M. Am. Soc. C. E., then Chief Engineer, at Pueblo, Colo., and at Las Vegas, N. Mex. In October,

* Memoir compiled from information supplied by E. S. Rice, Asst. Engr., A. T. & S. F. Ry. Co., Chicago, Ill., and on file at the Headquarters of the Society.

1881, he was appointed Office Engineer at Topeka, Kans., and afterward was engaged with the late Lewis Kingman, M. Am. Soc. C. E., on the construction of the Chicago, Kansas and Western and the Southern Kansas Lines of the Company. Mr. Dailey then served as Assistant Engineer on Maintenance at various places in Colorado, Missouri, and Illinois, until 1887, when he was transferred to the office of the Chief Engineer at Topeka, where he remained until May 15th, 1904, when he was given a leave of absence on account of ill health.

He was the first person to receive a pension from the Atchison, Topeka and Santa Fé Railway Company on account of faithful and efficient service. He had previously declined a pension from the Government for which he had applied, in order to refute the allusion that possibly his views regarding pensions, that an able-bodied man should not draw a pension, were prompted by a non-pensionable record. He refused to acknowledge that he was disabled as long as he was earning a living and claimed that the chronic rheumatism which had incapacitated him—contracted while in the service—was a badge of honor.

Mr. Dailey was a man of strong individuality and unimpeachable integrity, hospitable, and kindly. In Topeka, he had been familiarly known as "Diagonal Dailey", due to the fact that he had forced the State to construct diagonal walks through the State House grounds which are in the heart of the city and cover two square blocks. In 1906, he had removed to East Orange, N. J., where he died on February 9th, 1922. He is survived by his wife, four sons, and one daughter.

Mr. Dailey was a member of Lincoln Post No. 1, G. A. R., of Topeka, Kans. As a Thirty-second Degree Mason, he was a member of Siloam Lodge No. 225, of Topeka, and he was also a member of the First Unitarian Church of Orange, N. J.

Mr. Dailey was elected an Affiliate of the American Society of Civil Engineers on September 7th, 1904.

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OF THE

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OF

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AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PROCEEDINGS

This Society is not responsible for any statement made or opinion expressed in its publications.

SOCIETY AFFAIRS

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ITEMS OF INTEREST

The Committee on Technical Activities and Publications will be glad to receive communications of general interest to the Society, and will consider them for publication in *Proceedings* in "Items of Interest". This is intended to cover letters or suggestions from our membership concerning matters which are not of a technical character. Such communications, however, must not be controversial or commercial.

Report of Committee on Prizes

The report of the Committee to Recommend the Award of Prizes, comprised of Messrs. Thomas H. Wiggin, *Chairman,* George W. Kittredge, and

George R. Putnam, was presented to and accepted by the Board of Direction at its meeting held at San Francisco, Calif., on October 3d, 1922. This report is as follows:

"The Committee on Prizes has examined and considered the various papers eligible. These include papers to be published in Volume LXXXV of *Transactions* and are the papers published in *Proceedings* from August, 1921, to May, 1922, inclusive (together with subsequent discussions as yet unpublished), with the exception of papers by D. B. Steinman, M. Am. Soc. C. E., on 'Locomotive Loadings for Railway Bridges', William M. Hall, M. Am. Soc. C. E., on 'Some Notes on the Location and Construction of Locks and Movable Dams on the Ohio River, with Particular Reference to Ohio River Dam No. 18', and E. C. La Rue, M. Am. Soc. C. E., on 'Tentative Plan for the Construction of a 780-Foot Rock-Fill Dam on the Colorado River, at Lee Ferry, Arizona', which are not to be published in Volume LXXXV. The Committee begs to recommend awards, as follows:

"The NORMAN MEDAL to Charles H. Paul, M. Am. Soc. C. E., for Paper No. 1502, 'Core Studies in the Hydraulic-Fill Dams of the Miami Conservancy District'.

"The J. J. R. CROES MEDAL to William Cain, M. Am. Soc. C. E., for Paper No. 1483, 'The Circular Arch Under Normal Loads'.

"The THOMAS FITCH ROWLAND PRIZE to Gustav Lindenthal, M. Am. Soc. C. E., for Paper No. 1496, 'The Continuous Truss Bridge over the Ohio River at Sciotoville, Ohio, of the Chesapeake and Ohio Northern Railway'.

"The JAMES LAURIE PRIZE to Arthur T. Safford, M. Am. Soc. C. E., and Edward Pierce Hamilton, Esq., for Paper No. 1503, 'The American Mixed-Flow Turbine and Its Setting'.

"The ARTHUR M. WELLINGTON PRIZE, no award.

"The COLLINGWOOD PRIZE FOR JUNIORS, no award.

"The only papers on Transportation are relatively brief ones contained in the various Symposiums, and while of interest and value to the Society, are not of sufficient scope and dignity to be worthy of the Wellington Prize.

"The Collingwood Prize for Juniors cannot be awarded as there is no paper by a Junior.

"Your Committee found a large number of excellent and valuable papers and had difficulty in deciding between them, owing to the variety of subjects and the impossibility of saying with assurance that a meritorious paper on one subject is more worthy than a meritorious paper on another subject. Questions also arose as to interpretation of the rules under which the various prizes are awarded. A brief statement of decisions reached is here given for the possible benefit of future committees.

"The terms of the Norman and Croes Medals are apparently intended to be rather strict as to previous publication. In this age, however, nearly everything of interest is published in some form in organization bulletins or in the technical press previous to its appearance in more finished shape in the proceedings of technical societies. A close study of the working of the rules in the light of this fact reveals ambiguities which permit various interpretations. Your Committee has taken the liberal interpretation that the rule was intended to prevent prior publication of practically the same paper before another society or in the technical press.

"Another question was as to the force of the provision in the rules of the Rowland and Laurie Prizes that preference be given to papers describing works of construction. The great mass of papers do not fall under this head; for example, the many papers in the Symposiums are descriptive of progress in art and methods rather than descriptive of physical works. There are descriptions also of floods and flood problems, compilation of flood data, etc.

If the rule means that when there is a paper describing physical works it shall be given the prize in preference to papers of greater excellence which are not descriptive of physical works, then many excellent descriptive papers are ineligible for any prize. In recommending the award of the Laurie Prize to the paper on 'The American Mixed-Flow Turbine and Its Setting', your Committee used the broader interpretation that greater excellence in other papers might overcome the preference for papers describing particular works of construction.

"Your Committee notes that it is the intention of the Board of Direction to give more dignity and publicity to the award of these prizes.* Perhaps, in addition, it would be well to emphasize in the notices the specifications under which these prizes are awarded to the end that more papers may contain the data which have been so wisely provided for in the specifications and which we find to have been too frequently curtailed or omitted. It is evident that few if any of the papers have been prepared with a view to meeting the specifications for the prizes, and it is also a matter of regret that no papers were submitted to the Society, qualified or apparently intended for the Wellington and Collingwood Prizes."

Fall Meeting of the Society, San Francisco, Calif.

At the concluding session of the Fall Meeting at San Francisco, John R. Freeman, President, Am. Soc. C. E., pronounced the meeting a great success. Many factors contributed to this result. The attendance was large, the registration reaching 633, and included 133 engineering students, who came by special invitation, from the Student Chapters at the University of California and Leland Stanford Junior University. The technical program on "The Water Power Problem" proved interesting and instructive. The excursions were admirably planned and executed. Throughout the meeting, the efforts of the Local Committee on Arrangements were commended generally by those who had had the good fortune to enjoy this example of the cordial hospitality of the San Francisco members. The report of the meeting will be found on page 705.

Visits of Secretary to Local Sections

In connection with the trip to and from San Francisco, Calif., Secretary Dunlap visited 14 of the 39 Local Sections of the Society. Stops were made at Ann Arbor and Detroit, Mich., Chicago, Ill., St. Louis, Mo., Kansas City, Mo., Topeka, Kans., Omaha, Nebr., Denver, Colo., Salt Lake City, Utah, Portland, Ore., Seattle and Spokane, Wash., Duluth, St. Paul, and Minneapolis, Minn., and Iowa City, Iowa. In general, luncheon and dinner meetings were held, at which the subject under consideration was the work of the Society. In accordance with the policy of the Board of Direction, the Secretary hopes to be able to visit the remaining Sections, as time permits. In this manner, the widely extended activities of the Society will be brought personally to the attention of the members. It should be added that the interchange of ideas, enjoyed on this Western trip, is proving both helpful and inspiring.

* For rules governing the award of prizes and also the rules governing the preparation of papers submitted to the Society for publication, see 1922 Year Book, pp. 27 and 37, respectively.

Meetings of Special Committees

The attention of members is called to the Minutes of Meetings of the Special Committee on Bridge Design and Construction, the Special Committee to Codify Recent Practice on the Bearing Value of Soils for Foundations, etc., and the Special Committee on Irrigation Hydraulics, on pages 714 to 716, inclusive, of this number of *Proceedings.*

Memorial Fund for Henry Bazin

Under the sponsorship of Allen Hazen, M. Am. Soc. C. E., about fifty American engineers have made a substantial contribution to the work of the French Committee in charge of securing a fund for a memorial to the late Henry Bazin, the illustrious hydraulic engineer. The work on the memorial was necessarily postponed until after the World War. The Committee was then enlarged, and subscriptions were received from other countries. The French Committee has prepared a medal in commemoration of this event, copies of which have been distributed among the American subscribers. A replica of this medal has been placed in the Reading Room of the Society.

French Exchange Professor Begins Work in United States

The international movement of teachers has steadily gained in proportions and significance during the last fifty years.

A definite and permanent organization of international exchange of professors began in 1897 with the gift of $30 000 to the Cercle Française of Harvard University to endow an annual lectureship in Cambridge to be filled by distinguished French scholars and publicists.

M. Emanuel de Margerie, of the University of Strasbourg, French Exchange Professor in Applied Science and Engineering, has arrived in the United States to take up his work for the academic year 1922-23 in seven of the leading technical schools.

Professor de Margerie at once began work at Columbia University, where he is lecturing on Applied Geology, especially as applied to Topography. He will also appear at Harvard, Cornell, Johns Hopkins, Yale, Massachusetts Institute of Technology, and the University of Pennsylvania. The American Exchange Professor under this arrangement is Dean John Frazer, of the University of Pennsylvania, who has already begun his task in France.

Professor de Margerie, who succeeds Professor Jacques Cavalier, has won distinction as a teacher and author and in the public service. His name has become most widely known through his French translation of Eduard Suess' masterpiece, "Das Antlitz der Erde."

In conjunction with Professor Albert Reim, of Zurich, he published, in 1888, a treatise on "Dislocations of the Earth's Crust", fixing the nomenclature of Structural Geology in French, English, and German; and, in the same year, with General de la Noe, of the Geographic Service of the French Army, he published one of the first systematic accounts of land forms.

His "Catalogue of Geology Bibliographics", printed in 1896 for the International Congress of Geologists, was another important contribution to the literature of earth sciences. During the World War, as Secretary of the Geological Section of the Committee appointed in Paris to study the problems of frontier adjustment, Professor de Margerie prepared a series of maps and a special report on the Sarre coalfield. His latest work, the first volume of which has just been published, is a monograph on the structural geology of the Jura Mountains of France and Switzerland, written under the auspices of the French Geological Survey.

Professor de Margerie is Director of the Geological Survey of Alsace and Lorraine and Chief Geologist of the Geological Survey of France, besides holding many other posts of honor, such as Vice-President of the French National Research Council and of the Comité des Travaux Historiques et Scientifiques of the Department of Education; member of the French Institute of Anthropology and Associate Editor of the *Annales de Geographie,* member of the Institut d'Histoire, de Geographie, and d'Economie Urbaines de la Ville de Paris; Doctor in Science H. C. of the University of Lausanne; and Correspondent, Geological Society of America. Other distinctions include Honorary Member and Cullum Medallist of the American Geographical Society; Foreign Member and Lyell Medallist of the Geographical Society of London; Past-President and Prestwich Medallist of the Geographical Society of France; Past-President and Malte-Brun Medallist of the Geographical Society of Paris; and General Secretary of the International Conference on the Map of the World.

Election of Director of Engineering Foundation Announced

Alfred D. Flinn, M. Am. Soc. C. E., was elected as Director of Engineering Foundation, at a meeting of the Engineering Foundation Board, on September 14th, 1922. Mr. Flinn is the first incumbent of the new office which was created to meet the expanding activities of the Foundation.

He will retire as Chairman of the Engineering Division of National Research Council, a position which he has held since October, 1921, but will continue as Secretary of the United Engineering Society, in order that the Foundation may continue intimate relations with the Founder Societies. Mr. Flinn has been Secretary of that Society and of the Foundation since January, 1918.

REPORT OF CHARLES WARREN HUNT, SECRETARY EMERITUS, SPECIAL DELEGATE TO THE SEVENTY-FIFTH ANNIVERSARY OF THE KONINKLIJK INSTITUUT VAN INGENIEURS, THE HAGUE, HOLLAND, TO THE BOARD OF DIRECTION*

OCTOBER 31ST, 1922.

THE PRESIDENT AND BOARD OF DIRECTION
AMERICAN SOCIETY OF CIVIL ENGINEERS:

DEAR SIRS.—Confirming a cable message received July 31st, 1922, to the Society, I received the following under date of July 28th, 1922:

"DEAR SIR,

"We have the honor to inform you that the General Meeting of this Institute, on proposal of the Council, have by resolution of July 28th, 1922, conferred upon you the honorary membership of the KONINKLIJK INSTITUUT VAN INGENIEURS, on the occasion of the 75th anniversary of its foundation, the celebration of which will take place on September 8th, 1922.

"We have the pleasure to invite you to favor us with your presence at the General Meeting, which will be held at The Hague, on that day at 11 o'clock A. M., that you may personally receive the diploma from the hand of the president.

"In awarding this distinction to you, the highest which our Institution can grant, we wish to give you also a proof of our gratitude for the kindness which you, as secretary of The American Society of Civil Engineers, have always been ready to bestow upon our Institute and its members.

"We express our hope, that your honorable Society will be able to be represented at our celebration by a delegate.

"S. G. EVARTS,
"president.

"R. A. VAN SANDICK,
"general secretary."

President Freeman did me the honor to appoint me to represent the Society as its official delegate to this celebration, and I now beg leave to report.

I sailed on August 19th, reached Rotterdam twelve days later, and arrived at The Hague, September 1st, one week in advance of the date of the celebration.

While I was quite ill during much of my stay in The Hague, and was forced to refuse many kind invitations to visit engineering works, I had opportunity to renew my acquaintance with Mr. Van Sandick, Secretary, and with a number of other Dutch Engineers whom I had known in years past, and whom I had been fortunate enough to be able to help in the accomplishment of the objects of their visits to America, and also to meet many prominent representatives of other countries, including all of those mentioned later in this report, a number of whom were old acquaintances, notably Mr. F. von Emperger, from whom since my return I have received a delightful letter in which he refers to his visit to America 28 years ago, when he wrote two papers and several discussions which were published by the Society, and says: "In fact I am always looking upon you as my teacher of Technical English".

* This report is here published for the information of the membership, by order of the Committee on Technical Activities and Publications, prior to its presentation to the Board of Direction, which will not meet until January 15th, 1923.

Among other things, I had the pleasure of attending the Annual Meeting of the Delftsche Ingenieurs, composed of graduates of the University, held in the very interesting city of Leiden, and everywhere I was met with expressions of appreciation of the help given to Dutch Engineers through the American Society of Civil Engineers, and of the action of the Society in sending a representative to attend the ceremonies of the 75th birthday of the Institute.

The celebration took place on September 8th, and, if I may be permitted to refer to an entirely personal matter, this was also the 39th Anniversary of my wedding, and, as Mrs. Hunt was with me, the celebration acquired additional interest to us.

First there was a reception tendered by the President and Officers of the Institute to the Official Delegates and engineers to whom Honorary Membership was to be presented.

This was followed by a general meeting held in the large theatre of the Koninklijk Zoologisch-Botansche Genootschap, at which President Evarts made a formal address and presented the diploma of Honorary Membership to a number of engineers, among whom were Charles le Maistre, Secretary, British Standards Committee, F. von Emperger, Delegate of the Austrian Engineers and Architects, and Gen. C. J. Snijders, who commanded the Army of the Queen during the World War.

There were also present as Delegates, M. E. Barthelemy, Société des Ingénieurs Civils de France; L. Dellies, Société Belge des Ingénieurs et des Industriels; T. A. Van der Willigen, American Society of Mechanical Engineers; G. J. Th. Bakker, American Institute of Electrical Engineers; E. Fraser Smith, North East Coast Institution of Engineers and Shipbuilders; R. A. Dana, Institution of Naval Architects; P. V. Hunter, The Institution of Electrical Engineers; P. Meyer, Verein Deutscher Ingenieure und Architecten Verein; and many other delegates from Netherlands Scientific and Industrial Associations.

In presenting your representative with the diploma of Honorary Membership, President Evarts, speaking in English, said:

"I want to address a few words to our friends from the States. The great war, in destroying the direct steamship communication and intercourse especially between the Netherlands and their colony Netherlands-India, substituted another temporary route, with the United States of America as inter-medium. At that time, when traveling from India to Holland and *vice versa,* our members always met with a kind reception and professional aid from the secretaries of the great Engineering Societies abroad. So the annihilation of normal navigation, which has handicapped us so very severely, has had one fortunate consequence, the growing of collegial relations between our Institute and the American sister-societies.

"Mr. Ch. Warren Hunt: You retired from the function of Secretary of the American Society of Civil Engineers, and, after 28 years of active service, you became Secretary-Emeritus. It is already 19 years ago that we delegated our general secretary to America to make the personal acquaintance of the American Engineering Societies, of which that of the Civil Engineers is the oldest and the most important. He reported how much you did for him. Since then you must have spent a great deal of time

in helping Netherland engineers, who came to you with an introduction of our council, which serves to certify that they are engineers and members of good standing. And now you have crossed the Atlantic with the double object of receiving personally the certificate of Honorary Membership and of representing your honorable society at the ceremony of to-day. I thank you with all my heart for the pains you have taken.

"We trust that you will consider the honorary membership as a real distinction."

After the address of the President and the presentation of Honorary Memberships, the meeting continued with an historical address by Secretary Van Sandick, with lantern slide accompaniment, showing the growth of the Institute. The whole party then was entertained at luncheon, and, later, the meeting was resumed and two papers, both relating to affairs and engineering work in Dutch East India, were presented.

At five o'clock in the afternoon, a reception was held at the House of the Institute and here the President made an address to the members. The house which has been newly acquired by the Institute was inspected, and all the members seem to be very proud of the new quarters.

The concluding ceremony was a formal banquet in the evening, at which your representative was very pleasantly and honorably placed between one of the representatives of the Queen, H. A. Van Ijsselsteijn, Minister of Agriculture, and the Mayor of The Hague.

Many speeches were made, and I was called upon as the representative of American Engineers.

I am sure the Board will understand it is not an easy matter to speak at a banquet of this kind, where everybody speaks in a language that is entirely unfamiliar, and while almost all the engineers present understand English somewhat, they do not always catch the exact meaning.

I quote from the official organ of the Institute, received since my return, the first paragraph of what I was understood to have said, as follows:

"Speaker to whom the certificate of Honorary Member was handed to-day by the President, expresses his thanks for the distinction, in his own name and in particular in the name of the American Society of Civil Engineers of which he was Secretary for 28 years and which sent him on a special mission to Holland to represent it at these exercises and to tell the Institute how much it appreciates the great honor bestowed on it by this appointment. The American Society of Civil Engineers has great esteem for this Institute, not only on account of the important scientific work done by the Institute and its members, but it considers itself its younger brother. You are now 75 years old, while the Am. Soc. of C. E. will be only 70 years old in November."

This is a literal translation of that paragraph.

The report goes on to say that the speaker gave an interesting summary of the growth of the American Society of Civil Engineers and of the three other great Engineering Societies of the United States; described how they were endeavoring to co-ordinate and what they had accomplished so far, especially calling attention to the fact that they are joint owners of the Engineering Building. He also described other efforts at co-operation and presented letters of congratulation from the President of the United Engineering Society, the Chairman of the Engineering Foundation, and the

Chairman of the Division of Engineering of the National Research Council; that the speaker pointed out that societies of engineers were essential to the development of the Profession and to the maintenance of high standards; and through their publications and meetings, as well as international congresses held under their auspices, exercised not only a great influence locally, but also internationally.

He pointed out that, inasmuch as the work of the engineer at the present time must be more or less along special lines, and the tendency is naturally toward a somewhat narrow outlook, it is essential in every country, as in Holland, that there should be a Central National Society where all engineers may meet on a common basis as practitioners of that great constructive profession, the proper development of which is essential to the progress of civilization.

This banquet concluded a most interesting and delightful celebration, and one which, in the opinion of your representative, will have a lasting effect in cementing the cordial relations which exist between the scientific and professional associations of all countries.

I am satisfied, therefore, that my decision to make the long journey for the sole purpose of being present on that occasion, notwithstanding poor health and other deterrent reasons, was justified by the results accomplished.

Respectfully submitted,

Chas. Warren Hunt.

REPORT ON THE PROPOSED BENEVOLENT FUND, TOGETHER WITH ARGUMENTS IN OPPOSITION BY DIRECTOR CHESTER

At its meeting of October 2d, 1922, the Board of Direction instructed the Secretary to publish in *Proceedings* the Report of the Committee of the Board of Direction to Investigate and Report in Regard to the Desirability of Creating a Benevolent Fund, together with arguments against the creation of such a fund by Director Chester.

The Board of Direction will welcome the opinion of members and of Local Sections in regard to the recommendations of this report.

Report of Committee*

March 13, 1922.

To the Board of Direction,
American Society of Civil Engineers,
New York, N. Y.

Gentlemen.—The Committee appointed to investigate the establishment of a Benevolent Fund in connection with the Society would submit the following report:

The Committee is of opinion that such a Fund, to be maintained by voluntary subscriptions from the members and managed apart from, but in co-operation with, the Society itself, should now be established. Its primary object would be to extend financial assistance, in emergency, to worthy and necessitous members, disabled by sickness, accident, or other causes. A secondary, but equally desirable, object would be to render such assistance to the families of deceased members.

The most casual observation must be convincing of the need of such a fund; few members of the Society can fail to have had their attention directed to conditions experienced by Society Members, which trifling assistance, timely afforded, could have ameliorated or averted. Individual generosity may and does afford much relief, but that can well be reinforced, if not substituted, by organized co-operation, designed to meet sudden emergency by prompt and effective action.

It is clearly recognized that careful discrimination must be exercised in the allocation of assistance rendered and that the management must be entrusted to men who possess the judicial as well as the sympathetic temperament, and who can devote time and patience to an exacting though worthy task.

The Committee is of the opinion that such Benevolent Fund should be National in scope and operated by a central organization through the various Local Sections. With that fundamental conception, a draft of a Constitution of such organization is herewith submitted. That draft has been modeled upon the form of a similar foreign organization, modified to fit the probable conditions.

Alternatively, much relief may be secured through systematic efforts, conducted by the various Local Sections. It may well be that the initiation of such a fund should be confined to the Local Sections, stimulated thereto by the recommendation and endorsement of the Board of Direction, of the fundamental principles of the movement.

* The members of this Committee are Messrs. George G. Anderson, *Chairman*, George H. Clark, and Robert A. Cummings.

The Committee respectfully submits these suggestions and opinions, tentatively, recognizing the need of their elaboration and improvement, in the hope that they may be favorably considered and, finally, incorporated in a working plan.

Draft of Constitution

The Benevolent Fund of the American Society of Civil Engineers

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Rules

Name

1.—This Institution shall be called "The Benevolent Fund of the American Society of Civil Engineers".

Object

2.—The object of the Benevolent Fund is to afford assistance to necessitous Members, Associate Members, and Affiliates of the American Society of Civil Engineers, and their families, and to the families of deceased Members, Associate Members and Affiliates of the American Society of Civil Engineers. Also, to any one who may have been a Member, Associate Member, or Affiliate of the American Society of Civil Engineers, and have paid his subscriptions for five years consecutively, at least, or to the family of any such person.

Capital and Income

3.—The Fund shall be supported by means of Donations and Bequests, and Annual Subscriptions of not less than..................................

4.—All donations and bequests received, or promised, prior to ...., shall be considered as Capital, and shall be invested in the names of the Trustees of the Benevolent Fund of the American Society of Civil Engineers in............................ and no part of such funds so invested shall be withdrawn from Capital, except by a resolution authorizing such withdrawal passed at a General Meeting of the contributors especially convened for the purpose.

5.—All donations received subsequent to.............................. shall, unless otherwise directed by the Donors, be available for affording assistance to the persons eligible to receive such assistance, subject to the limitation contained in Rule 8.

6.—All annual subscriptions, and all dividends and interest arising from capital, shall be considered as income, and shall be applicable to the payment of grants and the assistance of applicants, and to the payment of necessary charges and expenses.

7.—The accumulations of income, unexpected donations, and bequests (if any), which may arise from year to year, after payment of all the grants and other charges and liabilities of the fund, may, in the discretion of the Committee of Management, be invested.

8.—The Committee of Management may annually apply in assistance a sum not exceeding the income of that year, as defined in Rule 6; and it shall be competent for the contributors at any General Meeting to authorize the application of a larger sum.

Privileges of Contributors

9.—The following contributors to the Fund shall be entitled to vote at all General Meetings, *viz.:*

Annual subscribers of not less than Five Dollars ($5.00), who shall have one vote for every Five Dollars ($5.00) subscribed, and Donors of not less than Fifty Dollars ($50.00) in one payment who shall have one vote for every Fifty Dollars ($50.00) so given.

10.—Votes may be recorded personally or by proxy upon all questions, except the election of the Committee of Management; and for such election they may be recorded by delivery to the Secretary of a list issued by the Committee, under Rule 13, after erasure or substitution, by the voter, of names thereon, in accordance with the conditions of Rule 14.

11.—Annual subscriptions shall be payable in advance on the 1st of January in each year, and no subscriber whose subscription is in arrears shall be entitled to any privileges as to voting or otherwise.

Committee of Management—Constitution, Duties and Powers

12.—For conducting the affairs of the Fund there shall be a committee, to be called the "Committee of Management", consisting of sixteen (16) members, and composed as follows: The President, for the time being of the American Society of Civil Engineers, and one contributor to the Fund from each District of the American Society of Civil Engineers, and five of whom shall be members of the Board of Direction of the American Society of Civil Engineers. These fifteen members shall be elected by the contributors at the Annual General Meeting, and five shall not be eligible for re-election until the expiration of one year. No member of the Committee shall serve for more than three years consecutively, and the Committee shall determine by lot, when necessary, which five members shall be ineligible.

13.—The Committee shall prepare, and shall cause to be issued to the contributors to the Fund, at least one month before each Annual General Meeting, a paper containing a list of persons eligible to serve on the Committee for the ensuing year, and stating the names of the five members of the Committee who are ineligible for re-election. This list shall contain the names of contributors to the Fund, being also either Members, Associate Members, or Affiliates of the American Society of Civil Engineers, and such list shall be the list for the election of the Committee.

14.—At the Annual Election, every contributor may erase any name or names from the list, and may substitute the name or names of any other person or persons eligible to serve on the Committee; but the number of names on the list after such erasure or substitution, must not exceed fifteen, including five members of the Board of Direction of the American Society of Civil Engineers, nor shall it contain the names of the five members, or any of them, who are ineligible. Those lists which do not accord with these directions shall be rejected by the Tellers.

15.—The President of the American Society of Civil Engineers shall be the Chairman of the Committee of Management, and, in his absence, the members present shall choose a Chairman from among themselves. Five members of the Committee shall be a quorum, and a majority of the quorum may make grants and do all acts within the powers of the Committee of Management.

16.—In the event of the death, resignation, or inability to act, of any of the Committee of Management, the Committee shall elect another member to supply the vacancy until the next Annual General Meeting.

17.—The Committee of Management shall have full power to make grants and to afford assistance to any necessitous Members, Associate Members, or Affiliates of the American Society of Civil Engineers, or to their families, or to the families of any deceased Member, Associate Member, or Affiliate of the American Society of Civil Engineers; also to any one who may have been a Member, Associate Member, or Affiliate of the American Society of Civil Engineers, and have paid his subscriptions for five years consecutively at least, or to the family of any such person, whether such recipient shall be or shall

have been a contributor to the Fund or not; and the fact of having been a contributor to the Fund shall not in any case constitute a claim to participate in it.

In the exercise of the powers above mentioned, the Committee of Management will co-operate with and secure the counsel of the Boards of Direction of the Local Sections of the American Society of Civil Engineers in the various Districts, and, for the purpose of affording immediate relief in cases of urgent necessity, may apportion the annual income among the various Districts, making such grant as the Member of the Committee of Management and the Board of the Local Section may award, subject to the approval and confirmation of the Committee of Management at its next regular meeting.

18.—The Committee of Management may, for the conduct of the affairs of the Fund, from time to time, make such regulations as are not inconsistent with these Rules, as they shall deem to be expedient.

19.—The Committee of Management shall have the appointment and removal of all such officers and employees connected with the Fund as they may from time to time think necessary, and may from time to time fix the remuneration to be paid to, and the services to be performed by, such officers and employees, respectively.

20.—The method of application for grants and assistance, and the nature of the recommendations to be required in support thereof, the qualifications and merits of the applicants, the amounts of the grants in individual cases, and also the purposes to which such grants shall be applied, and the advisability of their renewal, shall in every case be determined by the Committee of Management. All emergency grants must be confirmed at the first meeting of the Committee after they have been made.

21.—The Committee of Management shall have power to make investments in the names of the Trustees; to sign all checks for grants, and for all other payments and disbursements—such checks to be signed by the Chairman and one other member of the Committee present at the meeting at which such grants shall be confirmed, or payments and disbursements ordered, respectively; and to give receipts for all moneys, or to delegate this power from time to time to such person, or persons, as they may think fit.

22.—The Committee of Management shall not make any grants or payments by which the donations, bequests, or income of future years shall be anticipated or appropriated.

Meetings

23.—A General Meeting of the contributors to the Fund shall be held annually during the month of January, at the time of the Annual Meeting of the American Society of Civil Engineers, and at such General Meeting a report of the Committee of Management shall be presented, containing the names of all the contributors to the Fund, a statement of the number and amounts of all the grants made and assistance afforded during the preceding year, up to and inclusive of the 31st day of December, and of the general state of the Fund on the last named day, but it shall not be necessary to publish the names of the applicants for, and the recipients of, the assistance afforded by the Fund; the accounts shall be produced, with the report of the Auditors thereon; two Auditors shall be elected; and the Committee of Management shall be appointed in accordance with Rules 12, 13, and 14.

24.—Additional General Meetings may be called by the Committee of Management, and whenever the Chairman of that Committee shall be requested to do so, in writing, by Twenty Contributors to the Fund, in which request shall be specified the object for which the meeting is desired to be called; but no business shall be transacted at such meeting, or at any adjournment thereof, other than that specified in the requisition.

25.—The presence of at least ten contributors to the Fund shall be necessary for the transaction of business at any General Meeting, and if that number be not present within half an hour after the time appointed, the contributors present may adjourn the meeting.

26.—Any General Meeting may adjourn, if necessary, to any day not more than thirty days from the day of the original meeting.

27.—At every meeting, the President of the American Society of Civil Engineers, for the time being, shall take the chair, and, in his absence, a Chairman shall be chosen from among the contributors present.

28.—All General Meetings shall be called by notice sent to the contributors to the Fund at least one month before the day of any such meeting; and in all cases, such notice shall state the special and current business to be transacted.

29.—All questions introduced at any General Meeting shall be decided by the votes recorded in accordance with Rule 10, and should the votes be equal, the Chairman shall give a second or casting vote. Provided always, that no motion for altering the objects of the Fund, or for diverting any portion of the funds from the purposes herein specified, be adopted, unless at a General Meeting summoned for the sole object of discussing such motion, and unless the same be carried by a majority of at least two-thirds of the votes given at such meeting and be also confirmed by a like majority of the votes cast by letter-ballot sent to all the contributors to the Fund, canvassed not later than sixty days after the Meeting.

Auditors

30.—At the Annual General Meeting, two auditors shall be elected to act for the ensuing year, and they shall meet fourteen (14) days at least, prior to the next Annual General Meeting, and as often as necessary, to audit the accounts of the Fund, and they shall examine the accounts and the books, inquire into the state of the property and finances of the Fund, and report thereon to the Annual General Meeting.

31.—The term of the Auditors shall expire at the Annual General Meeting next after their election, but the Auditor last appointed shall be eligible for re-election.

32.—No person shall be at the same time an Auditor and a Trustee, or an Auditor and a Member of the Committee of Management.

Bankers

33.—The Banking Account of the Fund shall be kept at a bank in New York City, to be approved by the Committee.

Trustees

34.—Three Trustees shall be appointed at the first Annual General Meeting, in whose names shall be invested all the property of the Fund, except such as shall be from time to time in the hands of the Committee. When any vacancy arises, it shall be filled at a General Meeting, especially called for the purpose, within one month after such vacancy shall occur, and the remaining Trustees shall immediately transfer all property and funds into the names of themselves and the new Trustee.

The appointment of any Trustee may be revoked at a General Meeting, and a new Trustee appointed to fill the vacancy.

35.—The Trustees for the time being shall execute a Declaration of Trust of the property standing in their names belonging to the Fund.

36.—Each of the said Trustees shall be chargeable only for such moneys, funds, and securities as he shall actually receive, and shall be answerable and accountable only for his own acts, receipts, neglects, or defaults, and not for those of the other Trustees, nor for any Banker, Broker, or other person with

whom trust moneys or securities may be deposited, nor for the insufficiency or deficiency of the said moneys, funds, or securities, nor for any other loss, unless the same shall happen through his own wilful neglect or default.

37.—The Trustees shall from time to time pay over the dividends, interest, and annual income arising from the property of or belonging to the Fund, to, or permit the same to be received by, the Committee of Management for the time being.

New Rules and Alterations of Existing Rules

38.—Any new Rules may be made, and any of the foregoing Rules may be altered, amended or revoked by a General Meeting, provided the nature and effect of the proposed new Rules or alteration, amendment, or repeal be distinctly specified in the notice calling the meeting, and that the enactment, alteration, amendment, or repeal be determined on by a majority of at least two-thirds of those present, or voting by proxy, at such meetings.

Arguments in Opposition to the Establishment of a Benevolent Fund by John N. Chester, Director, Am. Soc. C. E.

Some of the arguments against the American Society of Civil Engineers establishing a Benevolent Fund, are, as follows:

(1) The idea seems to have originated in England where, after the war, there was a dearth of employment in all fields, and due, I think, largely to the persistency of the Englishman in adhering to his profession, and being disinclined to consider other means of livelihood, there appears to have been at this time calls for financial assistance from young Engineers.

This situation could be further charged to England's being over-populated and its natural resources fully developed, which cannot be the case in America for many years yet to come.

(2) I have practiced my profession for 32 years, during which time I have never come in contact with a member of the American Society who would admit being in such dire straits as to apply for benevolent aid. I was once encountered by an alleged Engineer to whom I contributed the sum asked, but after investigation proved him to be a fraud and never an Engineer.

(3) I have met many young men, some of whom were college graduates, who earned but a meager compensation considering their years of experience, and to these my advice, when asked, has been that I believed they would have done better as craftsmen and advised those whom I did not believe too old to enter that field.

(4) The American Society of Civil Engineers forswears any responsibility for the opinions or product of any of its members, and once admitted the Society seems extremely loath to take any adverse action regards a member's misbehavior; then why should it assume responsibility for his physical well-being, when it has side-stepped his mental and moral aspect?

(5) The American Society of Civil Engineers is not an employer and so has no responsibility concerning its members' ability to earn a livelihood.

(6) There exists no member but to whom is open many avenues through which aid can be procured when needed, for there is scarcely a city or county in the Union where the inhabitants are not taxed for such purposes. There is not a church active in the United States but has its charitable organization. Every fraternal order has its charity, and, lastly, there is no member but that through some insurance company, can make certain at all times a living income.

For the above reasons, I urge that the Society table indefinitely the matter of establishing a Benevolent Fund.

BIOGRAPHICAL SKETCH OF CANDIDATE FOR OFFICE TO BE FILLED AT THE ANNUAL ELECTION, JANUARY 17th, 1923

Theodore Lincoln Condron*

(Candidate for Director, District No. 8)

Born April 16, 1866, Washington, D. C. (Rose Polytechnic Inst., B. S. (in C. E.), 1890; M. S., 1894; C. E., 1918)—1890-91 Asst. Engr. under the late George S. Morison, Past-President, Am. Soc. C. E., Cons. Engr. on reconstruction of bridge over Mississippi River at Burlington, Iowa, for the Chicago, Burlington & Quincy R. R.: 1891-92 Draftsman and Computer: 1892-94 Instructor, Washington Univ., St. Louis, Mo.: 1894-1901 Res. Engr. at Chicago, Ill., for Pittsburgh Testing Laboratory, in charge of mill and shop inspection in Chicago Dist.: 1901 to date, private practice as Bridge and Structural Engr. in Chicago: associated with F. F. Sinks, M. Am. Soc. C. E., as Condron & Sinks, and, later, associated with Chester L. Post, M. Am. Soc. C. E., and John W. Musham, M. Am. Soc. C. E., as Pres., Condron Co., Cons. Engrs., engaged in designing and superintending construction of numerous railroad and highway bridges, industrial buildings of structural steel and reinforced concrete, for Mobile & Ohio R.R., Missouri, Kansas & Texas Ry., Chicago & Eastern Illinois R.R., Western Elec. Co., Wagner Elec. Mfg. Co., General Elec. Co., Baldwin Locomotive Works, Sears-Roebuck Co., International Register Co., Thomas A. Edison, Inc., U. S. Navy Dept., Bureau of Yards and Docks, South Park Commrs. of Chicago, and others; was appointed by Engineering Council in 1918 as Chairman of Committee on License or Registration of Engrs.; at present a Member of the Structural Engrs.' Comm. of the State of Illinois (Dept. of Registration and Education).

* Mr. Condron was appointed by the Board of Direction at its meeting of October 2d, 1922, to fill the vacancy caused by the death of A. S. Baldwin, M. Am. Soc. C. E., and, therefore, this biographical sketch could not be prepared in time to appear with the biographies of the Official Nominees in the October, 1922, *Proceedings*.

ACTIVITIES OF LOCAL SECTIONS*

Meeting of the San Francisco Section

The regular bi-monthly meeting of the San Francisco Section was called to order at the Engineers' Club on August 15th, 1922; President Thomas H. Means in the chair; A. T. Parsons acting as Secretary; and present, also, 33 members and guests.

Correspondence was presented from the Secretary of the Society announcing the shipment of a set of *Transactions* which are to be placed in the Library of the Engineers' Club; from the Secretary of Governor Stephens acknowledging the receipt of a letter from the Section regarding the filling of a vacancy on the Railroad Commission; and from the Duluth Section proposing that the Society constitute a Committee on Maps and Mapping with special reference to Map Scales.

For the Committee on Local Arrangements for the Fall Meeting of the Society, Mr. F. H. Tibbetts reported progress.

On behalf of the Excursion Committee, Mr. G. H. Binkley reported that about 100 members of the Section and their guests had accepted the hospitality of the San Francisco-Oakland Terminal Railways on August 12th, 1922, to inspect the proposed Joint Ferry Terminal. In connection with this excursion, on motion, duly seconded, the following resolution was adopted unanimously:

"The San Francisco Section of the American Society of Civil Engineers, through the courtesy of the San Francisco-Oakland Terminal Railway Co. was afforded the opportunity of a visit on August 12th to Yerba Buena Island. Explanations were made by Mr. E. M. Boggs, Consulting Engineer, and also by other representatives of the Company, of the proposed extension of the Key Route line to the Island with the establishment of a terminal on land to be filled in at the north, and a sheltered basin between the Island and this filled-in area.

"The members of this Section who participated in this visit of inspection are keenly appreciative of the opportunity thus presented to become acquainted not alone with a project which seems to provide a sensible and timely improvement to trans-bay transportation facilities, but also with a part of San Francisco visited by but few of her population.

"*Resolved, Therefore,* That this Section hereby extends thanks to the Terminal Railway Co. for its courtesies, which included steamboat transportation and a luncheon, and also to those who contributed toward making the visit to the Island pleasurable and instructive."

For the Committee on Standard Form of Contract, Mr. E. T. Thurston presented a report on the proposed Standard Form of Contract as suggested by the National Construction Conference. On motion, duly seconded, it was decided to consider this report at a special meeting of the Section to be called by President Means.

The address of the evening was delivered by Mr. C. E. Fleager, Plant Engineer for the Pacific Telegraph and Telephone Company, whose subject was "The Telephone Business of To-day". In the course of his address, Mr. Fleager gave a brief history of the telephone business, described the various types of

* For List of Local Sections, Officers, etc., see 1922 Year Book, p. 41, and p. 717.

instruments, cables, etc., used, the improvement in long-distance operation, the advantages of the automatic telephone, etc. Moving pictures showing the manufacture of cable and telephone apparatus at one of the plants of the Western Electric Company were also shown.

Meetings of the Cleveland Section

A meeting of the Cleveland Section was called to order at 12:15 P. M., at the Hotel Winton, on September 13th, 1922; President A. V. Ruggles in the chair; George H. Tinker, Secretary; and present, also, 6 members.

Mr. E. B. Thomas presented a verbal report relative to the activity of the Sewage Disposal Committee.

MEETING OF OCTOBER 11TH, 1922

A meeting of the Section was called to order at 12:15 P. M., at the Hotel Winton, on October 11th, 1922; Vice-President W. E. Pease in the chair; George H. Tinker, Secretary; and present, also, 14 members.

The minutes of the meeting of September 13th, 1922, were read and approved.

The Secretary presented a communication from Gardner S. Williams, M. Am. Soc. C. E., together with a resolution adopted by the Detroit Section relative to the Engineering Societies Service Bureau. On motion, duly seconded, the resolution was ordered filed, and the Secretary was instructed to arrange for the weekly bulletin of positions open to be posted on the bulletin board of the Cleveland Engineering Society.

The minutes of the meetings of the Associated Technical Societies of August 17th and September 27th, 1922, were read.

A resolution adopted by the Duluth Section relative to Maps and Map Scales was presented by Secretary Tinker, which resolution, on motion, duly seconded, was endorsed by the Section, and the Board of Directors was requested to appoint a Committee on Maps and Mapping including the subject of Map Scales.

Special Meeting of the Colorado Section

A special meeting of the Colorado Section was held at the Metropole Hotel, Denver, Colo., on September 26th, 1922; President Thomas H. Olds in the chair; Lyman E. Bishop acting as Secretary; and present, also, 29 members and 3 guests.

The minutes of the previous meeting were read and approved, and the report of the Auditing Committee for 1921 was also read and approved.

Mr. John H. Dunlap, Secretary of the Society, in whose honor this special meeting had been called, was introduced by President Olds, and reviewed briefly the work of the Local Sections and of the Society generally.

President Olds introduced Mr. Frank E. Winsor, Chief Engineer of the Board of Water Supply, of Providence, R. I., who spoke of the work being done by the Section in that city.

Mr. Arthur O. Ridgway, as Chairman of the Local Committee on Re-Districting, presented a progress report of the work done by this Committee and asked that the Committee be continued to make a final report. Inasmuch as Mr. Ridgway had been appointed by the President during the summer months, without authority from the Section, the President was authorized, on motion, duly seconded, to appoint a committee to study and report, at the next meeting of the Section, on the re-districting problem. President Olds subsequently appointed Messrs. Ridgway and Reedy as such committee.

At the request of Mr. W. W. Curtis, Secretary Dunlap presented, in a brief address, his ideas of the proper function of a Local Section.

President Olds outlined the program of the Section for the coming year, discussing some of the subjects which might be desirable and requesting that other members offer suggestions along the same lines.

On motion, duly seconded, a vote of thanks was offered Secretary Dunlap for his interesting talk.

Meeting of the Duluth Section

A regular meeting of the Duluth Section was called to order on October 16th, 1922, at 12:15 P. M.; President W. H. Hoyt in the chair; W. G. Zimmermann, Secretary; and present, also, 22 members and 7 guests.

The minutes of the meeting of September 18th, 1922, were read and approved.

President Hoyt announced that Messrs. Crago, Erickson, Greer, and Huntington had been notified of their election to membership in the Society.

Secretary John H. Dunlap of the Society, a guest at the meeting, presented a very interesting review of the activities of the Society and the development of an Engineers' world, during which he pointed out the obligation of the engineer to participate in the activities of mankind in the broadest way.

Executive Secretary L. W. Wallace, of the Federated American Engineering Societies, addressed the meeting on the subject "Future of the Engineer and the Federated American Engineering Societies."

Meeting of the Kansas City (Mo.) Section

A regular meeting of the Kansas City Section was held on September 22d, 1922, at the University Club; President John V. Hanna in the chair; Henry C. Tammen, Secretary; and present, also, 23 members and 1 guest.

The meeting was preceded by a dinner at which Mr. John H. Dunlap, Secretary of the Society, was the guest of honor.

Brief addresses outlining the work of the local engineering associations and their relations to each other were made by Messrs. John Lyle Harrington and Arthur C. Everham. In the course of these talks, particular attention was called to the Kansas City Engineers' Club and the acceptance of this organization by members of the Section and other local organizations as the medium for making their influence, as engineers, felt in civic affairs.

Secretary Dunlap then addressed the meeting on the activities of the Society. The address was followed by questions and general discussion which was participated in by nearly all members present.

Meeting of the Los Angeles Section

A meeting of the Los Angeles Section was held at the City Club, on September 13th, 1922; President R. J. Reed in the chair; F. G. Dessery, Secretary; and present, also, 38 members and 12 guests.

On motion, duly seconded, the following resolution was unanimously adopted:

"*Whereas*, it has pleased the Almighty God to remove from our midst our distinguished and beloved brother engineer and friend, Archie Lee Harris, and

"*Whereas*, we realize that in his death the American Society of Civil Engineers has lost an able and valued member, and

"*Whereas*, the Los Angeles Section, American Society of Civil Engineers, especially suffers from this loss,

"*Now, Therefore, Be It Resolved*, that the Los Angeles Section, American Society of Civil Engineers, hereby expresses its sense of great loss, and extends its deepest and most heartfelt sympathy to the bereaved family, and

'*Be It Further Resolved*, that these resolutions be spread upon the records of the Section, and a copy thereof be sent to the family of the deceased."

President Reed announced the details of the progam for the Fall Meeting of the Society to be held in San Francisco, Calif., October 2d to 9th, 1922, and requested a large attendance on behalf of the Section.

Mr. Arthur S. Bent addressed the meeting on the subject "Co-operation Between Engineers and Contractors". Mr. Bent emphasized the fact that the contact between the engineer and the contractor should be one of mutual confidence and co-operation, which is made difficult by the usual form of contract. Those engineers who realize this will welcome the efforts of the Society, the Association of General Contractors, the American Institute of Architects, the American Railway Engineering Association, and Highway Engineers, to develop a fair type of contract. He also discussed the work of the Association of General Contractors in bringing the construction industry to the high position in public confidence that its importance merits and, in closing, stated that co-operation must rest on a fair contract and on mutual confidence between contractors and engineers.

The subject was also discussed by President Reed, Messrs. R. P. Miller, W. D. Smith, S. A. Jubb, R. V. Leeson, E. T. Flaherty, W. K. Barnard, E. A. Rowe, T. D. Allen, M. C. Halsey, and Secretary Dessery.

Meeting of the New York Section

A meeting of the New York Section was called to order at the Engineering Societies Building on October 18th, 1922; President J. Vipond Davies in the chair; Harold M. Lewis, Secretary; and present, also, about 210 members and guests.

The personnel of the Standing Committees for the coming year was announced, and President Davies outlined the program being arranged by Mr.

Allen Hazen, as Chairman of the Program Committee. It is planned to have several subjects relating to the professional and personal relations of the engineer, and it is hoped to have Governor Morrow of the Panama Canal Zone speak on the Canal at one meeting. The Membership Committee, under Mr. George L. Lucas, is planning a campaign by which it is hoped to decrease the disparity between the number of members of the Society who are eligible for membership in the Section and those who actually become members.

Secretary Lewis presented a letter received in April, 1922, from the Acting Secretary of the Society in reference to a campaign for increased membership of the Society, but no action was taken, as the letter had been answered by the previous Board of Directors.

President Davies stated that he had had some correspondence on the proposed Charter Revision for the City of New York, but that nothing could be done in this connection until the type of charter was definitely determined.

M. Antoine, of Strasbourg, Engineer of the French Government, described the contemplated improvement of the Rhine and the Grand Canal d'Alsace, from Basle to Strasbourg. The address was illustrated by lantern slides showing existing harbors on the Rhine and the details of the proposed improvements.

The subject of the evening "Structural Engineering" was opened by Mr. James B. French, who presented for discussion the following resolution which was formulated by the Sub-Section on Design, which had held three meetings during the previous season:

"*Whereas,* the recent widespread attention directed to the disastrous theatre failures in Washington and Brooklyn makes this an opportune time to emphasize the importance of competent structural engineering in the construction of such buildings, and,

"*Whereas,* the responsibility of the structural engineer can only be effective if accompanied by commensurate authority covering both the design and construction of all parts of the building on which safety and stability are dependent,

"*Be It Resolved,* that the New York Section of American Society of Civil Engineers would be doing a public service and furthering the express objects for which it was organized by exerting its influence for such a reform in building laws and engineering practice as would make it impossible for any building in this Metropolitan District, where public safety is involved, to open its doors to public use until its safety and stability have been certified by a competent structural engineer."

Mr. French called attention to the flagrant violation of the laws in the construction of theatres which have recently collapsed and made a plea that the engineer be given authority to control both design and construction, expressing the belief that the requirements of some such certificate as that suggested in the resolution would be advisable.

The subject was discussed by the following: Mr. Rudolph P. Miller, formerly Superintendent of Buildings of New York City; the Hon. Lewis F. Pilcher, Architect of the State of New York; Mr. Daniel T. Webster, Manager, Marc Eidlitz Sons, Contractors, New York City; and Mr. Lewis D. Rights, Construction Engineer, Shoemaker-Satterthwait Bridge Company, New York City.

Mr. Miller stated that the trouble was not so much with the existing laws as with the failure to secure compliance with them, and that it is physically impossible for the Building Department of the City, as now organized, to handle all the work that comes before it, as the available force is insufficient. Mr. Pilcher stressed the need of more complete co-operation in design by the architect and the engineer, and of having the engineer who had co-operated in the design do the field inspection; he believes this to be the only real solution. Mr. Webster, speaking from the viewpoint of the general contractor, was in favor of design by a competent independent structural engineer, rather than by a steel contracting engineer, in the belief that it leads to fairer competition in contracting. He offered the suggestion that the Engineering Societies appoint a Board of Appeal to consider and rule on debatable questions which inevitably come up between the structural engineer and the contractor and that their decisions would form a code of practice to avoid similar troubles. Mr. Rights opposed the form of the resolution before the meeting as tending to place more responsibility on the engineer than is just; engineering is not an exact profession any more than the other leading professions, and the proper place for responsibility is on the owner, who, after all, gets the profit. He believes some form of Governmental control is needed to fix the responsibility where it belongs and offered the following amendment to the resolution under consideration:

"*Be It Resolved,* that the subject-matter of this evening's discussion be referred to a committee of three to be appointed by the President which shall consider this subject and refer it to the Board of Direction as to what action can be taken."

The resolution as amended was carried, with the understanding that a report of the action would be announced at a later meeting of the Section.

Previous to the business meeting, moving pictures were shown, illustrating the construction of the Gilboa Dam and the Shandaken Tunnel of the Catskill Aqueduct.

Annual Meeting of the Northwestern Section

The Annual Meeting of the Northwestern Section was called to order at the St. Paul Athletic Club, St. Paul, Minn., on October 17th, 1922; President W. T. Walker in the chair; Paul C. Gauger, Secretary; and present, also, 30 members and guests.

On motion, duly seconded, the minutes of the previous meeting were approved as recorded.

The Annual Report of the Secretary-Treasurer for the year ending October 17th, 1922, was presented by the Secretary, and, on motion, duly seconded, was adopted.

The Secretary presented a letter from the Minnesota Federation of Architectural and Engineering Societies stating that the Section was in good standing on the Federation records.

A letter from Gardner S. Williams, M. Am. Soc. C. E., together with a resolution adopted by the Detroit Section concerning the Employment Bureau of the Society, was presented by the Secretary. The subject was dis-

cussed by several members present and, on request, Secretary John H. Dunlap, of the Society, stated that the matter was under consideration and that efforts were being made to make the service as useful as possible. It was the consensus of opinion that the Section should wait until it was ascertained what steps the Society would take with regard to this Bureau, before taking action in this matter.

President Walker presented an informal report of the activities of the Section during the past year and, in behalf of the incoming officers, requested the earnest support of all members.

The following officers were elected: President, George H. Herrold; First Vice-President, James B. Gilman; Second Vice-President, A. M. Burt; and Secretary-Treasurer, Alvin S. Cutler.

Messrs. Paul C. Gauger and P. E. Thian were elected as representatives of the Section to the Minnesota Federation of Architectural and Engineering Societies.

After announcing the results of the election, President Walker introduced the newly elected officers who then took charge of the meeting.

Secretary Dunlap, who was present as a guest of the Section, was introduced and addressed the meeting on "The Activities of the American Society of Civil Engineers."

At the conclusion of the address, the members present discussed informally with Mr. Dunlap the question of increasing the membership in the Society, the question of an employment bureau, and of securing technical papers and the procedure for handling such papers.

At the conclusion of the discussion, a rising vote of thanks was extended to Mr. Dunlap for his visit to the Section.

MINUTES OF MEETINGS

OF THE BOARD OF DIRECTION

This is an abstract of the notes of the Secretary and subject to approval by the Board of Direction at its next meeting.

October 2d, 1922.—The Board met at 10:10 A. M., at the Palace Hotel, San Francisco, Calif.; Vice-President E. E. Wall in the chair; John H. Dunlap, Secretary; and present, also, Messrs. Anderson, Brown, Chester, Darrow, Davis, Dyer, Freeman (came in at 11:25 A. M., and assumed the chair), Grunsky (came in at 11:30 A. M.), Henny, Hogan, Holland, Hoyt, Huber (came in at 11:25 A. M.), Hudson, Humphrey, Pegram, Ridgway, Talbot, Winsor, and Yates.

After some discussion, the Board decided to recess and meet immediately as a Membership Committee.

Recess was taken for luncheon at 1 P. M.

The Board reconvened at 2 P. M., with the same attendance as in the forenoon.

Federated American Engineering Societies

It was decided to postpone the reading and approval of the minutes of previous Board and Executive Committee meetings and to invite Mr. L. W. Wallace, Secretary of the Federated American Engineering Societies, to address the Board, as the question of joining the Federation had been made the order of business for this meeting.

President M. E. Cooley, of the Federated American Engineering Societies, had also been invited to address the Board, but was unable to do so on account of illness. Secretary Wallace came in at 2:10 P. M., and addressed the Board for about an hour, outlining the aims, activities, and accomplishments of the Federation.

After a general discussion, Director Humphrey moved a rising vote of thanks to Secretary Wallace, which was seconded by Director Hogan, and unanimously carried. Secretary Wallace expressed his appreciation and withdrew at 3:15 P. M.

Director Humphrey moved that the regular order of business be taken up, which motion was duly seconded and carried.

The minutes of the meetings of the Board of Direction held June 19th and 20th, 1922, were presented for approval.

Subsequently, on motion of Director Humphrey, duly seconded and carried, the corrected minutes of the meetings of June 19th and 20th, 1922, were approved.

The minutes of the meeting of the Board held August 28th, 1922, were approved.

On motion of Director Humphrey, duly seconded and carried, the approval of the minutes of the meetings of the Executive Committee of July 18th, and

September 6th, 1922, was deferred until some of the items therein mentioned had been discussed.

On motion of Director Humphrey, seconded by Vice-President Grunsky, and carried, consideration of the question of joining the Federated American Engineering Societies was postponed until the evening session.

The Chairman appointed Messrs. Anderson, Darrow, and Yates, as Tellers to canvass the Membership Ballot. The Tellers subsequently reported, and the Chairman declared the election of candidates.*

The Secretary reported briefly for the Committee on Technical Activities and Publications.

Committee on Special Committees

Chairman Davis, of the Committee on Special Committees, presented the following report:

"Mr. President.—Your Committee on Committees has the honor to submit the following report:

"The question of appointing a Committee on Steel Columns and Struts, has been referred to this Committee, and has been given consideration.

"It is believed that there is need for work in this line, collecting and digesting existing tests, and extending these where required, and correlating results. It is recommended that the President appoint a committee of seven, to Determine the Strength of Steel Columns and Struts as shown by tests, and that this committee be authorized to enlist the co-operation of Engineering Foundation, if possible, and of any interested organization.

"The Committee has given consideration to the recommendation of the Duluth Section that a Committee on Maps and Mapping be appointed.

"We believe such a committee could do useful work, and should be appointed and instructed to investigate and report on the co-ordination of map making and publication, and on the need of speeding up the completion of the topographic map of the United States, and recommend measures to this end. The adaptability of maps to their use should also be considered.

"We recommend the President be authorized to appoint a committee of seven on Maps and Mapping, representative of the makers, publishers, and users of maps of all kinds.

"A. P. Davis,
"George H. Pegram."

Director Hudson moved the acceptance of the report, which was seconded by Vice-President Ridgway. Past-Presidents Talbot and Davis discussed the question of appointing a Committee on Steel Columns and Struts, referred to in the report, and Past-President Davis recommended that that part of the report be referred to the Committee on Research.

Director Hogan moved the adoption of the recommendation in the report, that the President be authorized to appoint a Committee of seven on Maps and Mapping.

Vice-President Ridgway seconded this motion, which was duly carried.

Director Hudson moved the adoption of the recommendation in the report, that the President be authorized to appoint a Committee of seven to Determine the Strength of Steel Columns and Struts. Director Yates seconded this motion.

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* See p. 702.

Discussion was participated in by Messrs. Davis, Hudson, Humphrey, and Talbot, during which Director Humphrey offered an amendment:

"That the matter be referred to the Committee on Research for report at the next meeting for further investigation as to the scope of the work of the proposed committee and ways and means of accomplishing it."

This amendment was seconded by Past-President Davis, and later accepted by Director Hudson, and carried.

Chairman Davis, of the Committee on Special Committees, presented the following further report:

"On behalf of the American Society of Refrigerating Engineers, this Society has been requested to designate a representative to serve on a Committee on a Safety Code for Mechanical Refrigeration. The existing committee is being placed on a representational basis. * * *

"A suggestion has been made that the Engineering Profession should have a universal telegraphic code especially adapted to the use of engineers and other technical purposes. We recommend that the President be authorized to appoint a Committee of five to investigate this subject, and submit recommendations."

Consideration was first given to the question of appointing a representative on the Sectional Committee on Safety Code for Mechanical Refrigeration of the American Engineering Standard Committee, of which the American Society of Refrigerating Engineers is the sponsor organization. Discussion was participated in by Messrs. Humphrey and Yates, and on motion of Director Hudson, duly seconded and carried, the President was authorized to appoint such representative.

The question of appointing a committee to investigate the wisdom of evolving a Universal Telegraphic Code specially adapted to engineers, was discussed by Messrs. Chester and Davis, and on motion of Director Winsor, seconded by Director Huber and carried, the recommendation of the Committee on Special Committees was adopted.

Chairman Humphrey, of the Committee on Licensing Engineers, asked for postponement until a later hour.

Chairman Brown, of the Committee to Consider the Whole Question of the Status of the Civil Engineer in Government Work and His Compensation, reported progress.

Committee on Professional Conduct

The Secretary read the following report from the Committee on Professional Conduct, to which Committee had been referred the letter of July 17th, 1922, from Robert A. Cummings, M. Am. Soc. C. E., concerning the circular from the Portland Cement Association, Chicago, Ill., in which it is stated that the Association will serve in an advisory capacity without cost to the public; also the letter of Director Chester in this matter, dated August 24th, 1922:

"New York, Sept. 19, 1922.

"To the Board of Direction of the
American Society of Civil Engineers:

"The Committee on Professional Conduct, to which was referred the matter of the complaint against the Portland Cement Association, in which the proposals of its circular of July 10th, 1922, are cited, finds as follows:

"1. The proposal in this circular to furnish free plans is confined to a number of plans for simple and useful structures to be built by farmers, not requiring ordinarily the services of engineers nor justifying as a rule the payment of an engineering fee. Manifestly this effort of the Portland Cement Association is to increase proper uses of cement and thereby benefit their business.

"We see in this procedure as stated in the circular no injury to the engineering business. Perhaps the employment of engineers by the Portland Cement Association more than offsets any benefits to the calling which might be derived from other sources.

"The practice of furnishing so-called free plans, if followed in other than minor structures, infringes upon the proper prerogatives of the engineer and engineers should oppose such action except as closely controlled by competent engineers.

"2. The offer of expert advice to engineers and architects appears to be within the well recognized practices of manufacturers in many lines of production. It should be recognized that such advice, while valuable, is liable to be lacking in completeness, calculated to favor a special product and intended to excuse its defects and belittle its proper substitutes. Engineers should not place reliance upon such publications except as the information contained therein will stand up under expert scrutiny wholly free from influences tending to favor the interest of a product to be marketed.

"There is no apparent way in which this Society can properly act other than by the presentation of these views and we recommend that this be done.

"George H. Pegram,
"A. M. Hunt,
"I. W. McConnell."

Discussion was participated in by Messrs. Anderson, Hogan, Humphrey, Pegram, and Talbot.

On motion of Director Humphrey, duly seconded and carried, the report was accepted, its recommendation approved, and a copy ordered to be forwarded to the Portland Cement Association.

On motion of Past-President Talbot, seconded by Director Humphrey, and carried, this report was ordered printed in *Proceedings*.

Chairman Humphrey, of the Committee to Report on Rearrangement of the Fifteenth Floor, reported progress.

Funds for Bust of Captain Eads

Chairman Wall, of the Committee on Collection of Funds for Bust of Captain Eads, reported progress. The net amount collected to date is $2 176.50, and Chairman Wall explained that the requirements of the Art Committee of the Hall of Fame of New York University had been raised, thereby increasing the expense of the proposed bust, which would necessitate the collection of further subscriptions amounting to about $1 200.

Discussion was participated in by Messrs. Anderson, Brown, Freeman, Chester, Darrow, Grunsky, Henny, Hogan, Holland, Humphrey, Ridgway, and Wall, as to ways and means of securing more funds. It was suggested that an appeal might be made to the Local Sections.

Vice-President Ridgway moved that the Secretary be requested to send a note to each of the members of the Board asking him to secure an amount

equal to one-twenty-eighth of the required sum. Director Chester seconded this motion.

Director Henny suggested that the Directors be furnished with a list of the names of contributors within their District.

Director Hogan suggested enlarging the Committee to 100 and taxing each member thereof.

Director Anderson finally offered an amendment to refer the matter back to the Committee with power to act, which amendment was accepted by Vice-President Ridgway, and duly seconded, and carried.

Report on Benevolent Fund

Chairman Anderson, of the Committee to Investigate and Report in Regard to the Desirability of Creating a Benevolent Fund, called attention to the draft of the report of his Committee, as submitted to the Board at its meeting of April 3d, 1922.

The matter was discussed by Messrs. Anderson, Brown, Chester, Grunsky, Henny, Hogan, Holland, Hoyt, Humphrey, Huber, and Talbot.

Director Brown moved that the report of the Committee, including the outline of the plan, be submitted to the Local Sections for discussion and report to the Board as to their views on the subject, which was duly seconded and subsequently carried.

The desirability of sending out arguments for and against the proposal was discussed.

Director Hoyt suggested that the report be published in *Proceedings* so that members of the Local Sections could refer to it, and Director Hogan suggested that individual members who are not members of Local Sections be asked for their opinions.

Director Humphrey moved that in sending out the notice only the plan be submitted without any arguments for or against. This motion was seconded by Director Hogan.

Director Henny offered as an amendment, which was seconded by Director Holland, and to which Director Humphrey stated he had no objection:

"That the Secretary be instructed to send out to the Sections the full Committee Report and also an argument against the proposal of the Committee drafted by Director Chester."

This was subsequently carried by an "aye" and "no" vote. As a result of the discussion, it was understood that both the complete report and Director Chester's argument against the proposal are to be published in *Proceedings*.*

On request, the Secretary read the report of the Committee, but not the outline of the plan.

Past-President Talbot reported progress for the Committee on Student Chapters.

Chairman Talbot, of the Committee on Research, reported progress.

It was reported that the question had come up as to whether this was a Special Committee of the Board of Direction or a Special Committee of the Society.

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* See p. 662.

Director Humphrey moved:

"That it is the sense of the meeting that this is a Special Committee of the Board."

This motion was seconded by Director Brown, and carried.

Chairman Brown, of the Public Relations Committee, reported progress.

Chairman Talbot, of the Committee on Honorary Membership, reported progress, and inquired whether it was planned to have ceremonies at the Annual Meeting of 1923 similar to those held at the Annual Meeting of 1922 in conferring Honorary Memberships.

Director Humphrey moved that that is the sense of the Board, which was duly seconded and carried.

Vice-President Ridgway, speaking for Director Holland of the Committee on Federal Charter, reported progress.

Director Humphrey, of the Committee on Districts and Zones, reported progress.

The Secretary reported on his visits to the various Local Sections en route to the meeting of the Board.

Technical Divisions

At the meeting of the Board on June 19th, 1922, it was decided that the proposed By-law covering Technical Divisions should be brought up for confirmation and approval at this meeting.

The Secretary reported that he had given this matter careful consideration and suggested certain changes in the proposed By-law. After extended discussion, participated in by Messrs. Anderson, Brown, Davis, Freeman, Grunsky, Henny, Hogan, Holland, Hoyt, Huber, Hudson, Humphrey, Talbot, Winsor, and Yates, the following By-law was adopted:

"Article VII—Technical Divisions

"1.—A Technical Division of the American Society of Civil Engineers may, by the action of the Board of Direction, be organized for the consideration of any engineering, scientific, or professional subject, provided that not less than 20 members of the Society unite in making written request for such an organization. Such a division shall be designated as ...... Division of the American Society of Civil Engineers. (The blank shall be filled by the title of the subject specialized.)

"2.—Members of the Society of any grade may become members of the Division by enrollment.

"Engineers and others not members of the American Society of Civil Engineers, desiring to participate in the work of the Division may be enrolled as Division Affiliates upon the approval of the Executive Committee of the Division. Such Division Affiliates shall not be in any sense members of the American Society of Civil Engineers in any grade, but shall have the privilege of attending meetings, presenting papers, and taking part in the discussions, but shall not have the right to vote.

"A Technical Division may levy division dues upon its enrolled members and affiliates by action of the majority of the Division Members, subject to the approval of the Board of Direction of the Society.

"3.—The Division shall elect annually an Executive Committee of 5 members of the Division who shall be Corporate Members of the American Society

of Civil Engineers, to have charge of its affairs under the guidance of the Board.

"Other Committees of the Division may be appointed by its Executive Committee.

"4.—The Division shall incur no financial obligations chargeable to the Society unless such are specifically authorized by the Board of Direction and provided for in its approved budget. No liability incurred other than as above provided shall be binding on the Society.

"5.—The Board of Direction of the Society may suspend or disband any Division, on 60 days' notice."

President Freeman retired at 5:50 P. M., and Vice-President Wall assumed the chair.

Recess was taken for dinner at 6:25 P. M.

The Board reconvened at 8:15 P. M., with the same attendance as in the afternoon.

Proposed Amendments to By-Laws

A notice of a proposed amendment to Article VI, Section 1, of the By-laws, was given by Director Humphrey at the meeting of the Board of Direction held June 19th, 1922, and a copy was forwarded to each Director on July 29th, 1922. The amendment was presented for final action, as follows: Strike out the first sentence, "Business meetings of the Society shall be held monthly on the first Wednesday of each month, except during the months of July and August", and amend the second sentence to read as follows: "In addition to the Annual Meeting and the Annual Convention, meetings for the transaction of business and for the reading and discussion of papers shall be held as ordered by the Board of Direction." This would make Article VI, Section 1, read as follows:

"1.—In addition to the Annual Meeting and the Annual Convention, meetings for the transaction of business and for the reading and discussion of papers shall be held as ordered by the Board of Direction.

Extended discussion in this matter was participated in by Messrs. Brown, Chester, Davis, Freeman, Grunsky, Henny, Hogan, Holland, Hoyt, Huber, Humphrey, Ridgway, Talbot, Wall, and Yates.

On motion of Director Hoyt, seconded by Director Anderson and carried, the President was authorized to appoint a committee of three to go over this matter and report at the next session of the Board. Further discussion was had as to the quality of papers published, attendance at Society meetings, method of accepting papers, etc.

The President subsequently appointed Messrs. Hoyt, Hogan, and Humphrey, as the Committee referred to.

At the afternoon session on October 3d, 1922, Chairman Hoyt reported that his Committee recommended that Article VI, Section 1, of the By-Laws be amended by striking out the words "on the first Wednesday of each month". This would make Section 1 read:

"1.—Business meetings of the Society shall be held monthly, except during the months of July and August. In addition to the Annual Meeting and the

Annual Convention, meetings for the reading and discussion of papers shall be held as ordered by the Board of Direction."

Director Humphrey moved the adoption of this Section thus amended, which was seconded by Past-President Davis, and carried by an "aye" and "no" vote.

Vice-President Wall, who was then presiding, announced that the By-law would be changed accordingly, this being the final action.

The Secretary suggested the following amendment to the By-laws: Amend Article IV, Committees, by adding after the words, in Section 1, "A Committee on Special Committees", the following words, "A Committee on Professional Conduct"; and by adding a new Section, as follows:

"6.—The Committee on Professional Conduct shall consist of three members of the Board of Direction. It shall consider and report to the Board of Direction upon such matters of professional ethics and conduct as the Board may refer to it."

and by changing the Sections now numbered 6 and 7, to 7 and 8, respectively.

Past-President Talbot questioned whether the Committee on Research should not also be included in the Standing Committees of the Board, which resulted in discussion of the whole matter of the status of committees, participated in by Messrs. Davis, Henny, Hogan, Humphrey, Pegram, Talbot, and Wall, but no action was taken.

The Secretary suggested, in order to correct the record, that as the name of the Publication Committee has been changed to "Committee on Technical Activities and Publications", Article IV of the By-laws should be changed by inserting before the last word in the last sentence of the fifteenth paragraph of Section 7, the words "Technical Activities and", making the sentence read:

"The printing of all reports of special committees shall be executed through the Standing Committee on Technical Activities and Publications".

Past-President Grunsky stated that he would give such notice of the proposed amendment, and the matter will come up for final action at the next meeting of the Board in January, 1923.

Candidate Nominated for Director from District No. 8

The Secretary reported that the "Second Ballot for Official Nominees" was canvassed August 15th, 1922, resulting in the nomination of A. S. Baldwin, M. Am. Soc. C. E., for Director from District No. 8. Mr. Baldwin died on June 26th, 1922, and the Secretary wrote to each member of the Board of Direction on August 16th, 1922, notifying him of that fact, and that a petition had been received from 132 members resident in District No. 8 requesting the Board to substitute the name of Theodore L. Condron, M. Am. Soc. C. E., for that of Mr. Baldwin. With this letter was enclosed a form of ballot to be filled out and returned for canvass at the Intermediate Meeting of the Board to be held August 28th, 1922. This action was taken because the Constitution provides that a list of "Official Nominees" shall be mailed to the Corporate Membership not later than the first day of October, and the Board did not meet until October 2d, 1922.

These ballots were never canvassed, as a letter questioning the above procedure, dated August 26th, 1922,* was received from Director Humphrey. Legal advice was sought in the matter, and a letter dated August 30th, 1922,† was received from Messrs. Parker and Aaron, explaining that this matter can properly be passed on by the Board at this meeting and that the requirement of the Constitution, that the list of Official Nominees be sent out on October 1st, is directory rather than mandatory.

The Executive Committee discussed this matter at its meeting on September 6th, 1922, and it was decided to ask the Board to safeguard future situations by delegating authority to the Executive Committee to act in a similar emergency after it has canvassed a letter-ballot vote of the Board in the matter.

Past-President Talbot moved that the name of Theodore L. Condron be supplied to fill the vacancy. This motion was seconded by Director Chester and carried.

Director Humphrey spoke against the delegation of power to the Executive Committee, as suggested, and Messrs. Davis and Hogan also spoke.

On motion of Director Humphrey, duly seconded and carried, the suggestion of the Executive Committee was laid on the table.

On motion, duly seconded and carried, the meeting was adjourned at 9:35 P. M., October 2d, 1922, to meet at 10:00 A. M., October 3d, 1922.

October 3d, 1922.—The Board reconvened at 10:05 A. M., at the Palace Hotel, San Francisco, Calif.; President John R. Freeman in the chair; John H. Dunlap, Secretary; and present also Messrs. Anderson, Brown, Chester, Darrow, Davis (came in at 10:10 A. M.), Dyer, Grunsky, Henny, Hogan, Holland (came in at 10:30 A. M.), Hoyt, Huber, Hudson, Humphrey, Pegram, Ridgway (came in at 10:25 A. M.), Talbot, Wall, Winsor (came in at 10:15 A. M.), and Yates.

Past-President Talbot offered the following resolution, which was seconded by Director Henny, and after discussion participated in by Messrs. Anderson, Chester, Grunsky, Hogan, Holland, Hudson, Humphrey, and Pegram, was carried by an "aye" and "no" vote:

"The Board of Direction feels that the method of nomination of officers of the Society given in the new Constitution should have a fair trial. It believes that the welfare of the Society demands that the methods of presenting the merits of candidates should be characterized by simplicity, inexpensiveness, and dignity.

"The membership of the Society is urged not to permit the elaboration of campaigning and the use of undue progaganda."

Reports from the Secretary on Various Activities

The following matters were reported for the information of the Board:

Canvass of Second Ballot for Nominees for Officers:—That, as authorized by the Board, President Freeman had appointed C. D. Drew, M. Am. Soc. C. E., as Chairman of the Committee of Tellers to canvass the "second ballots" for nominees for officers, which canvass was made on August 15th, 1922. The report of the Tellers was immediately forwarded each Director, and accept-

* See p. 695.

† See p. 696.

ances and biographical records have been received from each of these official nominees.*

Acceptances of Election to Honorary Membership:—That acceptances of election on June 19th, 1922, to Honorary Membership have been received from the following: Leon-Jean Chagnaud, Sir Maurice Fitzmaurice, Clemens Herschel, John F. Stevens, and W. C. Unwin.

Koninklijk Instituut van Ingenieurs:—That a cable received from Secretary Van Sandick of the Koninklijk Instituut van Ingenieurs of The Netherlands, stated that Charles Warren Hunt, M. Am. Soc. C. E., Secretary Emeritus, had been appointed an Honorary Member of that Society, and that this Society was invited to delegate him, or some other member, to represent it at the ceremony in celebration of the Seventy-fifth Anniversary of the Instituut on September 8th, 1922.

That President Freeman had appointed Dr. Hunt as such Delegate and that he had sailed on August 19th, 1922, to attend this celebration as the representative of the Society.

The Secretary read the letter from the President and General Secretary of the Koninklijk Instituut van Ingenieurs dated August 21st, 1922, transmitting a medal commemorating this anniversary.

Director Humphrey made the following motion which was seconded by Director Henny, and carried:

"That the President of the Society be instructed to acknowledge with thanks, on behalf of the Board, the receipt of the medal."

International Engineering Congress in Philadelphia, Pa., in 1926:—That President Freeman has appointed Messrs. George S. Webster and Richard L. Humphrey, as the representatives of the Society on the Board of Management of the International Engineering Congress to be held in Philadelphia in 1926, and that Mr. Webster and Mr. Humphrey have accepted the appointment.

That the plan adopted at the conference held in Philadelphia on July 19th, 1922, in this matter, provided that the organization meeting of the Board of Management should be called by the senior of the representatives of the American Society of Civil Engineers, and as it was desirable that such meeting should be held not later than November, 1922, President Freeman had appointed the representatives mentioned so that the meeting could be called.

National Safety Council:—That the letter of July 25th, 1922, from Secretary Williams, of the National Safety Council, invited this Society to send official representatives to its Eleventh Annual Safety Congress at Detroit, Mich., from August 28th to September 1st, 1922, and that President Freeman had appointed as such representatives, Messrs. G. H. Fenkell, Arthur H. Blanchard, and John C. Hawley.

American Engineering Standards Committee Invites Society to Appoint Representative on Sectional Committee on Hose Specifications:—That a letter of August 11th, 1922, from Secretary Agnew, of the American Engineering Standards Committee, explained that the Committee is organizing a Sectional Committee on Hose Specifications and invited the Society to designate a representative to serve thereon. This letter was forwarded to President Freeman, who is much interested in this matter and has kindly consented to serve on the Committee.

Washington Award:—That the term of R. C. Marshall, Jr., M. Am. Soc. C. E., as one of the representatives of the Society on the Washington Award, had expired on June 1st, 1922, and that President Freeman had reappointed Gen. Marshall as such representative.

Metric Conference:—That a letter of July 13th, 1922, from Secretary Parsons, of the American Chemical Society, had invited this Society to send a representative to the meeting held in Pittsburgh, Pa., on September 6th, 1922,

* *Proceedings*, Am. Soc. C. E., October, 1922, pp. 583 and 590.

on World Standardization *re* the Metric System, and that President Freeman had appointed Robert A. Cummings, M. Am. Soc. C. E., as such representative, who had accepted and attended the meeting.

Report of Committee on Prizes

The report* from the Committee on Prizes was presented.

On motion of Director Humphrey, duly seconded and carried, this report was received, and the recommendations therein contained were adopted. (It was explained that this Committee was asked to report at this meeting so as to enable the prizes to be awarded at the Annual Meeting of 1923.)

Report of Status of Recently Organized Special Committees

The Secretary reported that the following Committees have been organized:

Special Committee on Stresses in Structural Steel: F. O. Dufour, *Chairman,* Clement E. Chase, O. F. Dalstrom, J. H. Edwards, R. J. Fogg, F. M. Masters, L. D. Rights, F. E. Schmitt, and W. J. Thomas.

Special Committee on Flood Protection Data: N. C. Grover, *Chairman,* C. B. Burdick, William P. Creager, H. P. Eddy, Gerard H. Matthes, Charles H. Paul, and A. O. Ridgway.

Special Committee on Irrigation Hydraulics: D. C. Henny, *Chairman,* Samuel Fortier, *Vice-Chairman,* W. F. Allison, B. A. Etcheverry, R. L. Parshall, J. L. Savage, Fred C. Scobey, Stuart Sims, J. C. Stevens, and Franklin Thomas.

Special Committee on Impact in Highway Bridges: A. H. Fuller, *Chairman,* A. R. Eitzen, E. F. Kelley, Clyde T. Morris, and F. E. Turneaure.

Special Committee on Hydraulic Phenomena: (President Freeman has not yet appointed this Committee).

A request for an appropriation of $500 for the Committee on Stresses in Structural Steel was reported.

On motion of Director Humphrey, seconded by Director Hudson and carried, this was referred to the Executive Committee with power.

A request for an appropriation of $275 for the remainder of the year for the Committee on Impact in Highway Bridges, was reported.

On motion of Director Humphrey, seconded by Director Brown and carried, this was referred to the Executive Committee with power.

A request for additional appropriation of $1 000 for the Employment Service, was reported.

On motion of Director Humphrey, duly seconded and carried, this was referred to the Executive Committee with power.

Sanitary Engineering Division

The Sanitary Engineering Division has now been formed, and the five names which stand highest on the list of recommendations for members of its Executive Committee are as follows: Messrs. Kenneth Allen, Harrison P. Eddy, J. Frederick Jackson, X. H. Goodnough, and George T. Hammond.

* See p. 653.

On motion of Director Humphrey, duly seconded and carried, the Executive Committee was approved as named.

Engineering Foundation Lays on Table Request of Board to Make a Study of Engineering Society Organizations

The Board at its meeting on June 19th, 1922, adopted a set of resolutions* requesting Engineering Foundation to make a study of Engineering Society Organization, in an endeavor to overcome the existing confusion and duplication of activities in Civil Engineering organizations, and the other Founder Societies were asked to join with this Society in this request. The Board further referred to the Executive Committee, with power, the preparation of a financial plan in this matter.

The Secretary reported that a letter dated September 16th, 1922, has been received from Secretary Flinn, of the Engineering Foundation, stating that this matter was considered by Engineering Foundation at its meeting of September 14th, 1922, when it was reported that the other Societies were not in favor of this project. It was voted, therefore, to lay the matter on the table.

The following letter received from Secretary Flinn, of Engineering Foundation, dated September 13th, 1922, was presented:

"Among the projects suggested to Engineering Foundation there have been repeatedly various hydraulic problems. Unfortunately, resources have closely limited the work which could be done.

"Your Past-President Clemens Herschel was granted a modest sum for experiments on a new form of weir and he obtained valuable results.

"An investigation of arch dams, suggested and endorsed by members of your Society individually, is being organized on a basis of co-operation with governmental authorities, corporations owning dams and engineers experienced in design and construction.

"Engineering Foundation was proceeding further, in its attempts to meet this need, to develop co-operative undertaking of other hydraulic studies; but having received information from you of the three committees on hydraulic research being organized by your Society, Engineering Foundation desires to know in what way it can be most helpful as one of your agencies for research in conjunction with the other Founder Societies.

"Close co-operation should be established not only in this, but also in other fields between Engineering Foundation and your various research committees. Cannot the committee which serves as the Advisory Board on Civil Engineering Research for the Division of Engineering of National Research Council, also be the medium for co-operation with Engineering Foundation? Through this Committee details of co-operation with specific committees could then be arranged.

"Engineering Foundation would have the American Society of Civil Engineers and all the Founder Societies realize more fully that the Foundation is not an outside organization, but one of their own instrumentalities for conducting and furthering research in subjects of special interest to the members of the societies. It desires to be used more fully by the societies and to have their active assistance in increasing its resources and in realizing the aspirations of its Founder and the representatives of the societies who collaborated with him in establishing the Foundation."

On motion of Director Humphrey, duly seconded and carried, this matter was referred to the Committee on Research.

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* *Proceedings*, Am. Soc. C. E., August, 1922, p. 478.

Joint Finance Committee to Consider Contributions to Engineering Foundation by Founder Societies

For the information of the Board, it was reported that at the meeting of the Engineering Foundation Board, on September 14th, 1922, the following passage from the Address by President Freeman, at the Annual Convention of 1922, was read:

"The Engineering Foundation was established to aid in advancing Applied Science, and to aid in developing new data, by a far-seeing engineer who intended his own gift to be merely a nucleus to which others by adding might testify in a substantial way to the help they had received from association in the Engineering Societies and the researches of their predecessors; or, if they had prospered, might pay in like manner a part of their debt to the Profession.

"Cannot our Society take a more active part in making this great idea bear more fruit, both in increment to this fund and in adding to data for the practical engineer? Would it not show a finer spirit of appreciation toward those who build up this Foundation fund, if every dollar of its income from endowment was devoted to its main purposes, while the four National Societies took on themselves the whole expense of its administration?"

The Engineering Foundation Board decided to refer this to the Founder Societies' Joint Finance Committee for favorable consideration.

International Co-Operation of Engineers

A letter of introduction was given Dr. A. R. Ledoux before he went abroad, signed by the Presidents of the four National Societies. For the record, the following reply from the Institution of Civil Engineers, dated July 7th, 1922, was reported:

"Your letter of the 22d April, 1922, was received with much gratification by the President and Council of this Institution at their last meeting, when I had the pleasure of reporting to them also the very cordial greeting conveyed by Dr. Ledoux in person.

"The President and Council desired me to express to the four National Engineering Societies of the United States, through you, their acknowledgment and appreciation of the courteous message of good will thus communicated.

"In doing so may I express the pleasure which it gave me to meet Dr. Ledoux, both personally and as the representative of the Societies."

The Secretary further reported that there has been a great deal of informal discussion and correspondence regarding International Co-operation of Engineers, and a letter from the American Institute of Mining and Metallurgical Engineers under date of September 8th, 1922, states:

"In conformity with the suggestion of Dr. A. R. Ledoux, who has recently returned from a consultation with European Engineering Societies, President Dwight was authorized by our Executive Committee at a meeting held on September 6th, 1922, to appoint a committee of two from the Institute to confer with like committees from the three other Founder Societies, for the purpose of formulating a basis of co-operation between international technical bodies. President Dwight has appointed Albert R. Ledoux and Charles F. Rand as members of this Committee."

On motion of Director Henny, duly seconded and carried, the President was authorized to appoint a committee of this Society to co-operate with similar committees of the other Founder Societies.

Spring and Fall Meetings of the Society

The Secretary reported that invitations had been received from the Louisiana Section to hold the Spring Meeting of the Society, in New Orleans, in April, 1923; from the City of Richmond, Va., the Mayor, the State of Virginia, including the Governor, and the Chamber of Commerce, to hold the next Annual Convention in Richmond; and from the Illinois Section to hold the 1923 Fall Meeting in Chicago. Discussion on the subject was participated in by Messrs. Anderson, Chester, Davis, Freeman, Grunsky, Hogan, Hoyt, Huber, Humphrey, and Ridgway.

Vice-President Grunsky moved and Vice-President Ridgway seconded the motion, and it was carried, that it was the sense of the meeting that the Spring and Fall meetings of the Society should be held in New Orleans, La., and Chicago, Ill., respectively.

The Secretary explained the desirability of arranging a schedule of meetings a year in advance in order that proper accommodations may be secured, etc.

The following motion was made by Director Humphrey, and was duly seconded and carried:

"That the Spring Meeting be held in New Orleans in the month of April."

Allotment of Funds to Local Sections

The Secretary reported in regard to the allotment of funds to Local Sections, as the Executive Committee had asked that an investigation of the matter be made, and gave a brief résumé of the policy pursued by the Board, and asked for instructions in regard to certain cases.

On motion of Director Brown, duly seconded and carried, the President was authorized to appoint a Special Committee of the Board on Local Sections consisting of three members, and these matters are to be referred to this Committee.

John Fritz Medal Board of Award

It was reported that the term of Past-President A. N. Talbot as one of the four representatives of this Society on the John Fritz Medal Board of Award will expire on January 19th, 1923.

On motion of Director Humphrey, duly seconded, and carried, President John R. Freeman was appointed to fill this vacancy for a term of four years.

Board of Trustees of United Engineering Society

It was reported that the term of Past-President George H. Pegram as one of the three representatives of this Society on the Board of Trustees of the United Engineering Society will expire on January 25th, 1923.

On motion of Director Humphrey, duly seconded and carried, Mr. Pegram was re-elected for a term of three years.

Representatives on American Engineering Standards Committee

It was reported that the term of J. Martin Schreiber, M. Am. Soc. C. E., as one of the three representatives of this Society on the American Engineering Standards Committee will expire on December 31st, 1922.

On motion of Director Humphrey, seconded by Director Yates and carried, the filling of this vacancy was referred to the Executive Committee with power.

Report of Board of Direction

The Secretary reported that some provision should be made for the preparation of the Annual Report of the Board of Direction.

On motion of Director Humphrey, duly seconded and carried, the Chairmen of the Standing Committees of the Board were appointed a Committee to prepare such report.

Approval of Minutes of Meetings of Executive Committee

The approval of minutes of meetings previously postponed, was taken up.

On motion of Director Humphrey, seconded by Director Holland and carried, the minutes of the meeting of the Executive Committee of July 18th, 1922, were approved, as follows:

Minutes of Meeting of Executive Committee, July 18th, 1922

The Executive Committee met at 2:15 p. m.; President John R. Freeman in the chair; John H. Dunlap, Secretary; and present, also, Messrs. Pegram, Ridgway, and Treasurer Hovey.

The minutes of the last meeting of this Committee held April 18th, 1922, were reported to, and approved by, the Board of Direction at its meeting of June 19th, 1922.

Messrs. G. B. Strickler and J. S. Conway were appointed by President Freeman to attend the organization meeting held in Washington, D. C., on June 19th and 20th, 1922, of the American Construction Council, with a view to finding out the purposes of the Council and whether or not this Society should participate. Their report, dated June 26th, 1922, was presented, stating in part as follows:

"We are impressed by the need of a centralizing agency in the construction industry and believe it should receive the sympathy and moral support of the Engineering Profession. We do not, however, consider it advisable for the American Society of Civil Engineers to join the American Construction Council as an association member, for the following reasons:

"1. The project is somewhat outside of the general scope of the Society's activities.

"2. The engineer occupies a quasi-judicial position as adviser or arbiter in many construction matters, and the active participation of this Society as an organization in the American Construction Council would tend to weaken the strength of that position in the public mind."

On motion of Vice-President Ridgway, duly seconded, and carried, this report was received and ordered filed. The American Construction Council has accordingly been informed that this Society has decided not to participate directly in its activities although sympathetic to its aims.

It was reported that the Board at its meeting of June 20th, 1922, referred to the Executive Committee with power a letter from Stephen Child, M. Am. Soc. C. E., addressed to President Freeman concerning the establishment of clearing houses on Civic Improvement all over the world.

On President Freeman's request, more time was granted in this matter.

The following letter dated June 26th, 1922, from F. Lavis, M. Am. Soc. C. E., to President Freeman, was presented:

"Perhaps you will remember that several years ago (in 1916) during the Presidency of Mr. E. L. Corthell, a joint committee of members of the four National Societies was appointed and called the Pan-American Joint Engineering Committee. The purpose of this committee was to try and form some sort of closer relations between the engineers of North and South America. I acted as Secretary of this Committee during its life, and tried by correspondence with various societies in South America to develop something along those lines, but we did not meet with much success and owing to the entry of the United States into the war, the matter was crowded out and the committee disbanded.

"During my recent trip to Bolivia, I met some of the delegates to an Engineering Congress held in Lima at the time of the Peruvian Centennial last year, and had several lengthy talks with Dr. Julio B. Figueroa, who represented the 'Associacion Internacional Permanente del Congreso Sudamericano de Ferrocarriles', who was very keen about this matter of establishing closer relations between the engineers of North and South America.

"In December last I received a letter from Don Santiago Brian, of Buenos Aires, who is President of that Association, indicating the official interest of the Association in this idea and asking me to take it up with the engineers of the United States.

"I should have taken this matter up before, but have been very busy since my return from Bolivia in April. I think, however, that if any delegation of engineers is going to the Centennial in Brazil, that they might see what could be done to take further steps along these lines at that time.

"In any event I should like to have you keep this in mind and discuss it with the Board of Direction and perhaps bring it to the attention of the Council of the Joint Societies. If I can help any let me know, and in any event I should like to write to Mr. Brian about it, if we can tell him anything worth while."

After discussion, on motion of Past-President Pegram, duly seconded, and carried, the Secretary was instructed to see Mr. Lavis in this matter, as well as the Secretaries of the other National Societies, and others, and report back at the next meeting.

The Secretary was also instructed to write a friendly letter of inquiry to the Institution of Civil Engineers in London, asking to what extent co-operation is now in effect between the Institution and engineering organizations of South America.

It was reported that a letter of June 25th, 1922, from Mr. Sebastiao Sampaio, Brazilian Commercial Attaché, transmitted an invitation to this Society from the Club de Engenharia of Rio de Janeiro, Brazil, to participate in the International Engineering Congress to be held in Rio de Janeiro, September 7th to 30th, 1922, and that President Freeman had appointed the following delegates, other names also being under consideration: Messrs. Walter Charnley, C. W. Comstock, P. B. Easterbrooks, Verne Le Roy Havens, Leon C. Heilbronner, W. G. McConnel, Armando de Arruda Pereira, George Ribeiro, George Schobinger, Victor da Silva Freire, T. P. Stevenson, A. Y. Sundstrom, and B. S. Thayer.

It was reported to the June Board meeting that the term of Anson Marston, M. Am. Soc. C. E., as one of the representatives of this Society on the Engineering Division of the National Research Council would expire June 30th, 1922, and that under the rules he was not eligible for re-election at the present time.

The Board empowered the Executive Committee to fill this vacancy.

President Freeman reported that Director Marston had recommended to him the appointment of W. K. Hatt, M. Am. Soc. C. E., and on motion, duly seconded and carried, Mr. Hatt was so appointed.

Article VII of the Constitution provides that the Board shall, each year, review the existing geographical divisions and, if necessary, make changes in their boundaries. The Board empowered the Executive Committee to appoint a Committee on Districts and Zones to report to the Board at its January meeting, and the protests received from the Colorado and San Francisco Sections concerning the existing boundaries are to be referred to that Committee, together with the letter from W. H. Breithaupt, M. Am. Soc. C. E., suggesting the consideration of the possibility of having the whole of Canada a separate voting district. A letter received by President Freeman from Past-President Webster was presented, suggesting the appointment of Director Humphrey as Chairman of such Committee.

After consideration, the following committee was appointed: Messrs. Richard L. Humphrey, *Chairman,* George G. Anderson, Frank T. Darrow, John P. Hogan, and Walter L. Huber.

It was reported, for the record, that the Board had referred the invitation to appoint a representative on the Sectional Committee on the Safety Code for Mechanical Refrigeration, to the Committee on Special Committees for recommendation to the Executive Committee.

More time was granted the Committee on Special Committees.

A letter was presented, dated July 14th, 1922, from Chairman Stevenson of the Nominating Committee of the American Engineering Standards Committee, asking for suggestion of a member of this Society representing it on the Committee, to be nominated as a candidate for its Executive Committee for 1923.

On motion, duly seconded and carried, Director Yates was suggested for re-appointment, as such nominee.

It was reported that under date of July 5th, 1922, Henry Goldmark, M. Am. Soc. C. E., had written suggesting the appointment of a new committee, or the re-appointment of the old committee, on Steel Columns and Struts, copies of which letter had been forwarded to the Committee on Special Committees.

The action in referring this matter to the Committee on Special Committees was confirmed.

It was suggested that it might be well in this connection for the Committee on Special Committees to clarify the situation of the existence of the Bridge Committee, the Research Committees on Stresses in Structural Steel and on Impact in Highway Bridges, the two latter being authorized, but not yet appointed.

A letter dated July 2d, 1922, was presented from Mr. G. S. Radford, suggesting that the Society investigate subway dust collection.

After discussion, it was decided to refer this question to the Transit Commission.

A letter, dated July 17th, 1922, was presented from Robert A. Cummings, M. Am. Soc. C. E., calling attention to the circular letter from the Portland Cement Association, Chicago, Ill., stating that the Association will serve in an advisory capacity, without cost, to the public. Mr. Cummings stated that the effect of this is to injure the professional livelihood of a large number of engineers who have studied cement and concrete as a specialty and are at present unable to obtain adequate employment, and he asked to be advised of the disposition of this communication made by the Board.

On motion, duly seconded and carried, the letter was ordered sent to the Committee on Professional Conduct.

Messrs. Robert Ridgway, George H. Pegram, John P. Hogan, and William H. Yates, were appointed a committee to prepare a memoir of the late John A. Bensel, Past-President, Am. Soc. C. E.

The Board, at its meeting of June 20th, 1922, after learning that the Federated American Engineering Societies would discontinue the conduct of the Employment Bureau after July 1st, 1922, and that it would be turned back to the Founder Societies, adopted a resolution authorizing the Secretary to co-ordinate the service with the employment activities of the other engineering societies and directed him to continue the service as rendered in the past to the membership of this Society.

The following actions were also taken:

"That the Executive Committee be requested to investigate and report upon the feasibility of having clearing houses or registration bureaus established by each, or some at least, of the Local Sections of the Society to act in co-operation with the central committee and to report the cost of that kind of service."

Also,

"To include any further recommendations in connection with employment service which seem proper."

Also,

"That the Executive Committee consider also the desirability or undesirability of making a charge to those who make applications for position to the Service."

The Secretary further reported that the minutes of the Engineering Societies Employment Service of July 5th, 1922, state:

"*Voted:* That each society immediately pay $500 into the Treasury in order to meet current expenses, and hereafter and until further notice $350 on the first of every month."

After discussion, authorization was granted to pay the Service $500 now, and to continue monthly payments of $350 as suggested, but that the amount of $3 000 in the Budget for 1922 is not to be exceeded.

The Secretary was asked to look into the possibility of having the Local Sections establish clearing houses, as suggested, and report at the next meeting.

The Board, at its meeting of June 20th, 1922, referred to the Executive Committee with power, the request for an additional appropriation of $1 000 from the Special Committee on Bridge Design and Construction.

On motion of Past-President Pegram, duly seconded and carried, this request was granted.

The Board, at its meeting of June 20th, 1922, referred to the Executive Committee with power, and with recommendation for favorable action, the request of the Virginia and Toledo Sections for allotments.

On motion, duly seconded and carried, authority was allowed to grant allotments to members of these Sections, who have paid dues to the Section and who are in good standing with the Parent Society.

The Board, at its meeting of June 20th, 1922, referred to the Executive Committee with power, the matter of mileage and secretarial expenses of the Special Committee on Irrigation Hydraulics.

On motion, duly seconded and carried, $500 was appropriated to this Committee.

It was reported that Messrs. Quimby, Schreiber, and Yates, had attended the meeting in Washington, D. C., on June 15th, 1922, as representatives of the Society on the American Engineering Standards Committee.

On motion, duly seconded and carried, $100 was appropriated to defray mileage expenses of the above.

On motion, duly seconded, the sum of $75 was appropriated as the share of the Society of the expenses of Director Craver, of the Engineering Societies Library, to visit Denver, Colo., to assist in the organization of an Engineering Library there at the invitation of the Colorado Engineering Council. This

appropriation was made, provided the other three Founder Societies likewise contributed a similar amount.

To facilitate the work of the office, the amount carried by the Secretary in petty cash was increased from $1 500 to $2 500.

The Secretary was authorized to visit Local Sections, in passing, on his way to the Fall Meeting of the Society in San Francisco, Calif.

Adjourned at 5 P. M.

The minutes of the meeting of the Executive Committee of September 6th, 1922, were next considered, as follows:

MINUTES OF MEETING OF EXECUTIVE COMMITTEE, SEPTEMBER 6TH, 1922.

The Executive Committee met at 2:45 P. M.; President John R. Freeman in the chair; John H. Dunlap, Secretary; and present, also, Messrs. Pegram, Ridgway, and Webster.

It was announced that the minutes of the last meeting of this Committee held July 18th, 1922, had been forwarded each Director, and these minutes were approved.

The question of joining the Federated American Engineering Societies is to be made the order of business at the next meeting of the Board of Direction to be held October 2d, 1922, at San Francisco, Calif. The President and Secretary of the American Engineering Council of the Federated American Engineering Societies have been invited to be present at that time, and a report is to be rendered by this Committee as to the prospect of discharging the obligation if the Society is favorable to joining. At the last meeting of this Committee, the matter was postponed until more definite information was secured from Secretary Wallace of the Federated American Engineering Societies, and meanwhile the Secretary and Treasurer were asked to prepare a general statement covering the finances of the Society. A letter dated July 29th, 1922, from Secretary Wallace was presented, showing that the assessment for the American Society of Civil Engineers to join the Federation would amount to $10 853.46.

Financial statements were presented, showing expenditures to date under the various items of the 1922 Budget, with request for additional appropriations.

After careful consideration of the various items in the Budget, of the expenditures to date, and the probable expenditures at the end of the year, it was noted that the total expenditures would amount to about $250 300 and our entire income including interest, initiation fees, and income from the Fifty-seventh Street property would be in the neighborhood of $260 000 to $265 000. After further consideration of the ways in which the original budget of $237 930 had been exceeded, the Committee was of the opinion that, on the largest item, for Publications, activity should not be restricted; that there would probably be a saving next year of upward of $3 000 which was incurred in the present year from the overlapping in the office of Secretary and traveling expenses for the retiring Acting Secretary; that the extra expense incurred in the initiation of a Spring and Fall meeting was believed to be well warranted and should not be curtailed; that the only opportunity apparent now for substantial saving was in having two general meetings of the Board of Direction instead of four, and that it was believed that the intervening business could be carried on by the Executive Committee.

On motion of Past-President Webster, duly seconded and carried, it was decided to recommend to the Board of Direction, the approval of the additional items as set forth, amounting in all to $17 716.34.

On motion of Past-President Pegram, duly seconded and carried, it was decided also to recommend to the Board, the amendment of the present regulation for mileage allowance to the effect that such mileage allowance be at the

rate of 6 cents per mile for members of Committees and Directors, with no per diem subsistence allowance.

At the last meeting of this Committee, a letter was presented from F. Lavis, M. Am. Soc. C. E., dated June 26th, 1922, to President Freeman in the matter of establishing closer relations between the engineers of North and South America. This Committee instructed the Secretary to see Mr. Lavis and the Secretaries of the other Founder Societies and report back.

The Secretary reported, for the record, that several conferences were held, at which representatives from the Founder Societies were present, resulting in the soliciting of papers for the Brazilian Congress from experts in the various subjects of interest to South American engineers. These conferences (at which Messrs. Fred Lavis, I. W. McConnel, Milton H. Freeman, Verne LeRoy Havens, and Philip W. Henry, represented the Society), were well attended and proved interesting and helpful. All the members of the Society resident in Brazil have been urged to help make the Engineering Congress in Rio de Janeiro a success.

The Secretary was also instructed to write a friendly letter of inquiry to the Institution of Civil Engineers, asking to what extent co-operation is now in effect between the Institution and engineering organizations of South America and the following reply, dated August 21st, 1922, was presented:

"My dear Mr. Dunlap.—In reply to your letter of the 26th July, I have to say that this Institution's relations with engineers, both collectively and individually, in North and South America, have always been most cordial. A number of its members are in practice in the latter continent, and a number of papers have been published by the Institution from time to time on subjects of engineering interest in those countries, besides which the Institution is in close touch with the engineering Institutions in that part of the world.

"Our relations with the United States and, of course, with Canada have for a great number of years been even closer, and I need hardly remind you of the several occasions upon which visits have been exchanged between members of our Institutions. We are proud to count among our members a number of eminent engineers in these two countries, and we trust that the co-operation between engineers in this country and on the American continent may grow as time goes on."

The "Second Ballot for Official Nominees" was canvassed August 15th, 1922, resulting in the nomination of A. S. Baldwin, M. Am. Soc. C. E., for Director from District No. 8. Mr. Baldwin died on June 26th, 1922, and the Secretary wrote to each member of the Board of Direction on August 16th, 1922, notifying him of that fact, and that a petition had been received from 132 members resident in District No. 8 requesting the Board to substitute the name of Theodore L. Condron, M. Am. Soc. C. E., for that of Mr. Baldwin. With this letter was enclosed a form of ballot to be filled out and returned for canvass at the Intermediate Meeting of the Board to be held August 28th, 1922. This action was taken because the Constitution provides that a list of "Official Nominees" shall be mailed to the Corporate Membership not later than the first day of October, and the Board will not meet until October 2d, 1923.

It was reported that these ballots have not yet been canvassed, as the following letter, dated August 26th, 1922, questioning the procedure, was received from Director Humphrey:

"My dear Mr. Dunlap.—The ballot for a nominee to fill the vacancy in the eighth district in the list of 'Official Nominees' is in my opinion not legal. The Constitution provides for the selection of nominees to fill vacancies by the Board of Direction.

"The Board of Direction, therefore, is the only body that can authorize a ballot for this purpose; since the Board does not meet for the transaction of

business until October 2d, 1922, the ballot to be canvassed August 28th, 1922, is unauthorized by the Board.

"The list of 'Official Nominees' can be mailed to the corporate membership of the Society on October 1st, with a note stating that the result of the action by the Board of Direction in filling the vacancy caused by the death of Mr. A. S. Baldwin will be communicated to the members immediately after its meeting in San Francisco, Calif., October 2d, 1922.

"This matter is brought to your attention as the Secretary of the Board of Direction."

"Very truly yours,

"RICHARD L. HUMPHREY."

It was further reported that legal advice had been sought in the matter and the following letter, dated August 30th, 1922, was presented from Messrs. Parker and Aaron explaining that the matter can properly be passed on by the Board at its meeting on October 2d, 1922, and that the requirements of the Constitution that the list of official nominees should be sent out on October 1st, is directory rather than mandatory.

"NEW YORK, AUGUST 30, 1922.

"JOHN H. DUNLAP, ESQ., *Secretary,*
AMERICAN SOCIETY OF CIVIL ENGINEERS,
33 West 39th Street, New York City.

"DEAR SIR—We beg to acknowledge receipt of your letter of August 29th, 1922, enclosing copy of letter of the Secretary to the members of the Board of Direction, dated August 16th, 1922, and also of the letter of Mr. Richard L. Humphrey, dated August 26th, 1922.

"We summarize the facts as we gather them from your enclosures as follows:

"In the canvass of August 15th, 1922, of the second ballot for official nominees for directors, it appeared that Mr. A. S. Baldwin received the greatest number of votes as candidate from District No. 8. Mr. Baldwin died on June 26th, 1922. On August 16th, 1922, a letter was sent by the Secretary to each of the members of the Board of Direction requesting each member of the Board to ballot for another nominee for the office of Director from District No. 8, to be the official nominee in place of Mr. Baldwin.

"Your communication to us does not disclose by whose authority or direction the letter of August 16th, 1922, was sent out. No action was taken on the subject at a so-called intermediate meeting of the Board of Direction held on August 28th, 1922; and the ballots sent out with the letter of August 16th have not yet been canvassed, but it is proposed to canvass them at a meeting of the Executive Committee to be held on September 6th, 1922, and to send out the name of the person found to have received the greatest number of votes of members of the Board of Direction as the 'official nominee' for Director from District No. 8.

"Mr. Humphrey raises the point that the Board of Direction is the only body that can authorize a ballot to select such an 'official nominee', and that the next meeting of the Board of Direction at which such a matter can be attended to is the second day of October, 1922.

"You ask our opinion on two questions:

"Would the letter ballot which is taken, but not canvassed, if canvassed by the Executive Committee on September 6th, enable the Executive Committee legally to declare the person having the greatest number of votes on such canvass to be the 'official nominee' for Director from District No. 8, and justify the inclusion of his name in the list of official nominees to be sent on the first day of October to every corporate member?

"You ask further whether, assuming that the letter ballot were invalid, the Executive Committee as such could, at its meeting on September 6th, exercise the power of the Board of Direction to select such a nominee?

"Taking up first the matter of the ballot vote by the members of the Board of Direction, we make a general observation that as a matter of strict legal practice the Board of Direction or Trustees cannot take binding legal action by individual letters written by the members. The Board of Direction, like an ordinary business Board of Directors of a business corporation, must act in meeting and in person. They may not act by proxy nor by mail vote. We find nothing in your Constitution or By-Laws that exempts your Board of Direction from the usual requirements governing the action of Boards of Trustees or Directors. We are, therefore, of opinion that the letter ballot by the Board of Direction is not a legal method of fulfilling the requirements of your Constitution that the selection of the nominee shall be by the Board of Direction. This contemplates that the Board shall meet, confer, exchange views, and vote, only those present being entitled to have their votes counted.

"With respect to the second question: It may well be that the Board of Direction might have empowered the Executive Committee to act in such a matter as the designation of 'official nominees', where that duty was otherwise imposed upon the Board of Direction. It seems to us, however, that the resolution of January 19th, 1922, is hardly broad enough to confer such authority upon the Executive Committee. Their duties are first, routine matters, and second, emergency matters. Inasmuch as the matter of the election of a Director will not come up before the Society for action until next January, there is no immediate emergency in the affairs of the Society justifying the Executive Committee in assuming duties otherwise not delegated to them. In our opinion, the matter can properly be passed upon by the Board of Direction at its scheduled meeting on October 2d, 1922, and the nominee there selected may on that day be sent out to the membership. The requirements of the Constitution that the list of official nominees should be sent out on October 1st is what the lawyers call directory rather than mandatory. That is, the fact that the list was sent out 24 or 48 hours later would not make it in any respects illegal. It is simply a convenient date for the purpose of giving ample opportunity to the electorate to become familiar with the names of the nominees before deciding whether they wish to file independent nominations. The course suggested by Mr. Humphrey in the third paragraph of his letter would be legally valid and correct; it would, however, save a separate mailing to send the list and supplemental slip with the additional name out on the 2d or even on the 3d, which could be done without creating a condition that would make the nominations invalid.

"Very truly yours,

"PARKER AND AARON."

After discussion, it was decided to ask the Board to safeguard future situations by delegating authority to this Committee to act in a similar emergency after it has canvassed a letter-ballot vote of the Board in the matter.

The Secretary was instructed to have the ballots in question on hand at the meeting of the Board in October, 1922.

Past-President Webster left the meeting at 4:10 P. M.

The Secretary addressed the Committee in regard to securing publicity for the Society, and explained his ideas on the subject.

No definite action was taken, but it was suggested that the Secretary see various well-known men in this line and ascertain ways and means of accomplishing the desired end.

President Freeman here read a letter he had just received from David B. Rushmore, M. Am. Soc. C. E., against the licensing of engineers, which matter was discussed, but no action taken.

The Secretary presented his proposed itinerary of visits to the Local Sections en route to, and returning from, the San Francisco Fall Society Meeting, and reported that he planned to start on September 18th, 1922. This itinerary was heartily approved by the Committee.

A letter was presented, dated August 18th, 1922, from Mr. D. N. Dunlop, Organizing Director of the World Power Conference to be held in 1924 at the British Empire Exhibition, explaining that it has been arranged to hold the first World Power Conference during the Exhibition in the summer of 1924. The general scheme is set forth in a booklet which Mr. Dunlop sent, and he stated that he would be grateful for any assistance rendered. He called attention to the list of distinguished gentlemen who have consented to serve in this connection and stated that he was already in touch with the American Institute of Electrical Engineers and was writing to the Mining Engineers, the Mechanical Engineers, and the Power Club.

The Secretary was instructed to consult with the Secretaries of the other National Societies in this matter.

Reference was had to the letter from Stephen Child, M. Am. Soc. C. E., addressed to President Freeman concerning the establishment of clearing houses on civic improvement all over the world, which the Board at its meeting of June 20th, 1922, referred to this Committee with power.

It was decided to consult Nelson P. Lewis, M. Am. Soc. C. E., in this connection.

An invitation to be represented on a Joint Committee on the Delamater-Ericsson Historical Collection was received.

A letter of August 9th, 1922, was presented from Chairman H. F. J. Porter of this Committee, enclosing a statement, "A National Engineering Museum", explaining that it had secured the consent of the American Society of Mechanical Engineers to join and was now asking the other Societies to unite in endorsing the project. The letter continued:

"We desire to make this a National movement in which every engineer in the country will participate and trust that we shall secure the engineers in your field through your interested activity.

"As other Societies join the movement they will be represented on our Committee whose title will be modified appropriately and whose scope will be changed so as to be all inclusive instead of specific as at present.

"Of course, we cannot foretell what financial policy such a re-organized Committee will adopt, but at present it is not contemplated that the constituent Societies will do more than endorse the movement and assist in propaganda for its success by popular and private subscriptions.

"We should appreciate your appointing at your early convenience one or more representatives to take up this matter with us so that we can get the movement under way as soon as possible."

On motion, duly seconded and carried, the President was authorized to appoint a representative to attend a meeting on the subject and to report back.

At the meeting of the Board of Direction held on April 3d, 1922, a proposed amendment to the Constitution regarding the compounding of dues was reported. The Board referred the matter to the Executive Committee and at its meeting of April 18th, 1922, the Executive Committee laid the matter on the table.

(At the meeting of the Board on June 20th, 1922, Director Humphrey stated informally that he thought this should be taken off the table.)

A letter of August 14th, 1922, from Edward W. Howe, M. Am. Soc. C. E., addressed to the Executive Committee was presented suggesting an amendment to Section 5, Article IV of the Constitution, covering fees for compounding dues. The letter also encloses a letter written by Mr. Howe to Peter

Junkersfeld, M. Am. Soc. C. E., Chairman of the Committee on Referred Amendments, dated April 18th, 1921, with enclosures relating to the same matter.

The Secretary was instructed to reply to Mr. Howe explaining that this matter was previously laid on the table as it was felt that the new Constitution should not be amended for at least a year, and that his communications would be filed for future attention.

In order to facilitate the work of the office, it was suggested that the Executive Committee pass a resolution providing that the Preliminary Lists of which members of the Board indicate the classification of applicants for admission should be returned two weeks prior to the Board Meeting when the meeting is held outside of New York City and one week prior to the Board Meeting when the meeting is held in New York City.

The Secretary requested authority to disregard Preliminary Lists received from Board members after that date.

On motion, duly seconded and carried, this request was adopted.

In 1921, the Board authorized the issuance of cards to Juniors certifying to their membership in the Society. The resolution provided that these cards should not be sent to Juniors in arrears of dues. It has been found in practice somewhat difficult to handle, and it was suggested that hereafter the Secretary be instructed to forward cards to all Juniors on the first of each year.

On motion, duly seconded and carried, this suggestion was adopted.

It was reported, for the record, that President Freeman had appointed Messrs. Baxter L. Brown, Frank G. Jonah, and W. E. Rolfe, as a Committee to prepare the memoir of the late Robert Moore, Past-President, Am. Soc. C. E.

It was reported, for the record, that a telegram of condolence dated August 3d, 1922, had been sent to Mrs. Alexander Graham Bell, signed by the Secretaries of the four Founder Societies, and Secretary Flinn of the United Engineering Society, expressing sympathy on the death of Dr. Bell.

It was reported that, under date of August 9th, 1922, A. H. Sabin, Assoc. M. Am. Soc. C. E., had written President Freeman, outlining a plan for the publication of a journal of engineering abstracts, and copy of this letter was ordered sent each Director.

This matter is to come up at the next meeting of the Board with the approval of this Committee.

Advertising in *Proceedings* was discussed, and it was decided to refer this matter to the meeting of the Committee on Technical Activities and Publications, to be held October 2d and 3d, 1922, at San Francisco, Calif.

It was reported that the biographical records of Official Nominees for Offices to be filled at the coming Annual Meeting had been received and edited in the office and their publication in the October *Proceedings* was approved.

Adjourned at 6 P. M.

Director Humphrey moved that the recommended increase in the Budget amounting to $17 716.34, be approved, which was seconded by Director Yates and carried.

Past-President Talbot inquired as to several items of the Budget, which the Secretary explained.

Director Humphrey moved and Vice-President Grunsky seconded the motion, which was carried, that the suggestion of holding two general meetings of the Board instead of four be not approved.

In regard to the recommendation to amend the present mileage regulation, discussion was participated in by Messrs. Anderson, Chester, Hudson, Humphrey, Pegram, and Ridgway.

On motion of Director Humphrey, seconded by Director Chester and carried, it was decided to make no change in the existing regulation for mileage for Directors and members of Committees.

Vice-President Ridgway reported, as Secretary of the Alfred Noble Memorial Committee, that Hugh L. Cooper, M. Am. Soc. C. E., had resigned as a member of that Committee, and that Chairman Rea had suggested that J. Waldo Smith, M. Am. Soc. C. E., be appointed as Mr. Cooper's successor.

On motion of Director Humphrey, duly seconded and carried, the President was empowered to make this appointment.

Recess was taken for luncheon at 12:30 P. M.

The Board reconvened at 1:35 P. M., with the same attendance as in the forenoon.

Director Humphrey called attention to the matter of compounding dues which was laid on the table by the Executive Committee, and asked that that Committee comply with the request of the Board to report in the matter.

The approval of minutes of meetings was resumed.

The corrected minutes of the meeting of the Executive Committee of September 6th, 1922, were approved.

The informal recommendation made at the meeting of the Board on August 28th, 1922, for reconsideration of the decision made at the meeting of June 19th, 1922, with reference to facilitating the work on applications, consideration of which had previously been postponed, was taken up.

This matter was fully discussed by Messrs. Chester, Davis, Hogan, Hoyt, Humphrey, and Wall. The wisdom of having Directors scan and report only on applications within their Districts was considered, and the previous report of Vice-President Wall's Committee in the matter was discussed.

Director Hoyt made the following motion, which was duly seconded and carried:

"That a copy of the original report be sent to the members of the Board and that the Secretary be asked to make a study of it and send out a statement from the standpoint of the Secretary's office, in time for it to be taken up at the next meeting."

The following further motion made by Director Humphrey, and seconded by Director Yates, was carried:

"That it is the sense of this Board that each member of the Board shall hereafter scan all the names on the Preliminary Lists and report thereon."

Vice-President Wall retired from the meeting.

Committee on Licensing Engineers

Director Humphrey, of the Committee on Licensing Engineers, addressed the Board, and discussion on this subject was participated in by Messrs. Anderson, Brown, Chestér, Davis, Freeman, Grunsky, Henny, Hogan, Holland, Huber, Hudson, and Talbot.

On motion of Director Hogan, seconded by Past-President Davis and carried, the Committee on Licensing Engineers was instructed to bring in a report at the next meeting.

QUESTION OF JOINING THE FEDERATED AMERICAN ENGINEERING SOCIETIES

The question of joining the Federated American Engineering Societies was taken up.

Director Humphrey moved:

"That it is the sense of this meeting that the Society join the Federated American Engineering Societies."

This motion was seconded by Director Brown, and extended discussion was participated in by Messrs. Anderson, Brown, Chester, Davis, Grunsky, Henny, Hogan, Holland, Hoyt, Hudson, Humphrey, Pegram, Ridgway, Talbot, and Winsor.

Former Acting Secretary Chandler's letter, previously presented, was mentioned, and the financial aspect was considered with particular reference to the amount of funds assigned to Local Sections, and the possibility of postponement until the January, 1923, meeting when there would be fuller knowledge as to finances for next year and possibly other methods proposed for raising money.

Director Humphrey further moved:

"That his motion be made the order of business at the January meeting of the Board."

This motion was seconded by Director Henny, and carried by an "aye" and "no" vote.

Director Humphrey then offered the following motion:

"That this Board is sympathetic to joining the Federation when financial and other conditions permit."

Director Hudson asked for a roll-call on this. After some further discussion, this vote was taken with the following result:

"Ayes" (12): Messrs. Anderson, Brown, Chester, Darrow, Davis, Dyer, Freeman, Grunsky, Henny, Hoyt, Humphrey, and Talbot.

"Noes" (8): Messrs. Hogan, Holland, Huber, Hudson, Pegram, Ridgway, Winsor, and Yates.

The Board recessed at 5:10 P. M., to meet at 10:50 P. M., as a Membership Committee.

The Board reconvened at 10:50 P. M., with the same attendance as in the afternoon.

The report of the Membership Committee was presented.

On motion, duly seconded and carried, the recommendations of this Committee, which were not read, were adopted as the action of the Board.

The Board adjourned at 11 P. M., to meet at 8 P. M , December 4th, 1922, at the Headquarters of the Society.

OF THE SOCIETY

November 1st, 1922.—The meeting was called to order at 8:05 P. M.; President John R. Freeman in the chair; John H. Dunlap, Secretary; and present, also, 153 members and guests.

The minutes of the meeting of October 4th, 1922, were approved as printed in *Proceedings* for November, 1922.

The Secretary announced the election of the following candidates on October 2d, 1922:

As Members

George Lincoln Albert, Dayton, Ohio
Edward Bartow, Iowa City, Iowa
William Henry Crago, Duluth, Minn.
John Hazard Dorroh, University, Miss.
George Warren Elspass, Lakewood, Ohio
Roy Victor Engstrom, Wheeling, W. Va.
John Aubrey Foulks, Newark, N. J.
Edward Theodore Grandlienard, Philadelphia, Pa.
Gilbert Walter Hebblewhite, Evansville, Ind.
Benjamin Franklin Howland, Hilo, Hawaii
Joseph Husband, Sheffield, England
Otis Leon Leefers, Cedar Rapids, Iowa
Clair Victor Mann, Rolla, Mo.
Lewis Christian Mayer, York, Pa.
Eugene Henry Morey, Lincoln, Nebr.
Julian Cleveland Smith, Montreal, Que., Canada
Ora Kilburn Williamson, Edwardsville, Kans.

As Associate Members

Ellwood Harmon Aldrich, Wisconsin Rapids, Wis.
Roswell James Aydlotte, Chester, Pa.
John Samuel Bailey, Atlanta, Ga.
George Farnsworth Baker, Westport, N. Y.
Ira Steiner Barth, Atchison, Kans.
Owen W. Bauer, Los Angeles, Calif.
Charles Atwell Chaney, Pittsburgh, Pa.
Harold Francis Clemmer, Springfield, Ill.
Joseph Harrison Conzelman, Birmingham, Ala.
Alexander Davis Crosett, Brooklyn, N. Y.
Arthur Boyd Davis, New Orleans, La.
Richard Vincent Donnelly, Belleville, N. J.
Erik Joseph Eriksson, West Duluth, Minn.
William Joseph Frere, Jr., Council Bluffs, Iowa
Walter J. Fuston, Dallas, Tex.
Clinton Merritt Greer, Duluth, Minn.
Harry Pendleton Hart, Shanghai, China
Walter Edwin Hart, Chicago, Ill.
Perit Fitch Huntington, Minneapolis, Minn.

Joseph Barnard Jewell, Pontiac, Mich.
Thomas B. Kennedy, Jr., Chambersburg, Pa.
Ernst William Kurz, Ithaca, N. Y.
James Artemus Lewis, Birmingham, Ala.
Edward Heller Maier, Bridgeton, N. J.
William Norman Mitchell, Topeka, Kans.
Eugene Hiram Paddock, New York City
Roland Ralph Pyne, Ft. Thomas, Ky.
William Harold Ramp, New Martinsville, W. Va.
Charles John Rasch, Baltimore, Md.
Ray Longfellow Schoppe, Manila, Philippine Islands
Charles Morrison Scudder, Wauwatosa, Wis.
Charles Harmon Shook, Dayton, Ohio
Mortimer Wilson Smith, Jr., Clarksburg, W. Va.
Bayard Francis Snow, Seccondee, Gold Coast, West Africa
Howard Halsey Snyder, New York City
Edward John Spoerer, Jersey City, N. J.
Donald Cameron Stackpole, Bellefonte, Pa.
Maynard Joseph Steere, Radersburg, Mont.
Walter Eugene Stoddard, Sacramento, Calif.
Edwin Leonard Strandberg, Seattle, Wash.
Earl Charles Thomas, Stanford University, Calif.
Robert Ellsworth Thomas, Mare Island, Calif.
Ambrose Michael White, Bedford, Pa.

As Juniors

Glenn Harold Allen, Cincinnati, Ohio
Edward William Backes, New Haven, Conn.
Sam Cohen, Passaic, N. J.
George Hubert Cone, Fort Worth, Tex.
Edward James Costello, Jr., Verona, Pa.
Harold Lambuth Davis, Berkeley, Calif.
Joseph Ricketts Edmonston, Cincinnati, Ohio
Prudencio Esquivel y Frias, Ithaca, N. Y.
Curtiss Tarring Gardner, Waban, Mass.
Henry George Gerdes, San Francisco, Calif.
Franklin Hudson, Jr., Kansas City, Mo.
Joel Munson Johnson, Bayonne, N. J.
Donald Hull McCreery, Pasadena, Calif.
Grant Lenox Miner, Jr., Richland Center, Wis.
Herbert Augustus Olson, Lawrence, Kans.
Walter Lambuth Picton, Nashville, Tenn.
Robert Guyle Fenton Sarvis, Cincinnati, Ohio
Oscar Century Stupp, St. Louis, Mo.
Harold Coble Troxell, Los Angeles, Calif.
Webster Franklin Turner, Russellville, Ark.
Robert Raymond Waddington, Elizabeth, N. J.

The Secretary announced the transfer of the following candidates on October 3d, 1922:

From Associate Member to Member

Alexander Seymour Ackerman, Corozal, Canal Zone, Panama
Willard Townshend Chevalier, Brooklyn, N. Y.
George Jacob Davis, Jr., Tuscaloosa, Ala.
Edwin Leroy Driggs, Manila, Philippine Islands
George Garrett Edwards, Ennis, Tex.
Edgar Dow Gilman, Cincinnati, Ohio
William Robert Goodwin, Minneapolis, Minn.
Walter John Grodske, Manila, Philippine Islands
Manton Hannah, Waco, Tex.
James Carothers Harvey, Santa Fe, N. Mex.
Claude Alfred Latimer, Holyoke, Mass.
Harold MacLean Lewis, New York City
James Blair Long, Norristown, Pa.
Edgar Scott McCandliss, Topeka, Kans.
Samuel Brooks Morris, Pasadena, Calif.
Everett Bodman Murray, Washington, D. C.
Harry Longyear Preston, New York City
Ralph Dennis Rader, Bozeman, Mont.
John Revell, Fort Collins, Colo.
Lesslie Rielle Thomson, Montreal, Que., Canada
Arthur Carling Toner, Pittsburgh, Pa.
John Wilson Toyne, South Bend, Ind.
Earle Lytton Waterman, Iowa City, Iowa
Ralph Benjamin Wiley, West Lafayette, Ind.

From Affiliate to Member

Henry Sylvester Jacoby, Ithaca, N. Y.
Edward John Mehren, New York City

From Junior to Associate Member

Clarence Edward Keefer, Baltimore, Md.
William Lewis Stanton, Minneapolis, Minn.
Cornelius Van Eenenaam, Lansing, Mich.

The Secretary announced the following deaths:

Chester Harvey Chamberlin, of Fort Worth, Tex., elected Member, October 5th, 1904; died July 14th, 1922.

William Jewett Haskins, of New York City, elected Junior, March 7th, 1883; Member, December 1st, 1886; died October 9th, 1922.

Thomas Henry McCann, of Hoboken, N. J., elected Member, April 2d, 1890; died October 25th, 1922.

William David Uhler, of Harrisburg, Pa., elected Associate Member, May 6th, 1908; Member, March 1st, 1910; died October 27th, 1922.

Frank Sherman Washburn, of New York City, elected Member, November 7th, 1888; died October 9th, 1922.

B. F. Cresson, Jr., M. Am. Soc. C. E., Chief Engineer of the Port of New York Authority, addressed the meeting on "A Rapid Survey of Important European Ports, with an Inquiry into the Lessons to be Drawn from Them", illustrating his remarks with lantern slides.

The meeting was then opened for discussion, which was participated in by Col. Edward Burr, Corps of Engineers, U. S. Army, and Messrs. Charles C. Hurlbut, William G. Atwood, J. V. Davies, W. J. Boucher, H. C. Keith, D. J. Turner, and Nelson P. Lewis.

Adjourned.

SAN FRANCISCO, CALIF., MEETING

October 4th, 1922.—The First Session of the Fall Meeting of the Society was called to order at 10 A. M., at the Palace Hotel, San Francisco, Calif.; President John R. Freeman in the chair; John H. Dunlap, Secretary; and present, also, 368 members and guests.

President Freeman introduced John A. Britton, Affiliate, Am. Soc. C. E., Vice-President and General Manager of the Pacific Gas and Electric Company, who presented an address of welcome.*

President Freeman replied† to the welcome extended by Mr. Britton.

The Symposium on "The Water Power Problem" was opened by Arthur P. Davis, Past-President, Am. Soc. C. E., who presented a paper on "The Colorado River Development",‡ illustrating his remarks with lantern slides. Mr. Davis was followed by John P. Hogan, M. Am. Soc. C. E., whose subject was "Present Tendencies of Water Power Development in New York State".§ Mr. Hogan also illustrated his remarks with lantern slides. A paper by Oscar C. Merrill, M. Am. Soc. C. E., entitled "The Operation of the Federal Water Power Act"¶ was presented by the author.

The papers were followed by oral discussions of the subjects by Messrs. J. B. Lippincott, C. S. Jarvis, and D. C. Henny.

Past-President Charles D. Marx took the chair.

Announcements relative to excursions, etc., were made by Secretary Dunlap and A. H. Markwart, M. Am. Soc. C. E., Chairman of the Local Committee on Arrangements.

Adjourned at 12:30 P. M., to meet again at 8 P. M.

October 4th, 1922.—The Second Session of the Fall Meeting was called to order at 8 P. M.; President John R. Freeman in the chair; John H. Dunlap, Secretary; and present, also, 252 members and guests.

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* See p. 710.

† See p. 711.

‡ *Proceedings,* Am. Soc. C. E., November, 1922, p. 1738.

§ *Loc. cit.,* p. 1741.

¶ *Loc. cit.,* p. 1758.

In continuation of the Symposium on "The Water Power Problem", Gerard H. Matthes, M. Am. Soc. C. E., presented a paper entitled "Aerial Photography as an Aid in Map Making, with Special Reference to Water Power Surveys",* which he illustrated with lantern slides. The subject was discussed by Messrs. F. H. Tibbetts, who also illustrated his remarks with lantern slides, Louis C. Hill, and C. H. Birdseye.

A brief address presenting data on the design, development, and operation of hydro-electric plants in the United States, which have been collected by the U. S. Geological Survey, was made by J. C. Hoyt, M. Am. Soc. C. E., after which a film entitled "The Story of Water", was shown to illustrate the methods used by the U. S. Geological Survey in this work and the application of the results. Moving pictures showing the development and construction of the National Power Highways in the East, which were prepared under the direction of the Highway Engineers of the U. S. Bureau of Public Roads and the U. S. Department of Agriculture, were presented by J. W. Ball, Assoc. M. Am. Soc. C. E.

Secretary Dunlap and Mr. Markwart made further announcements relative to various matters in connection with the meeting.

Adjourned at 9:30 P. M., to meet again on October 5th, 1922, at 10 A. M.

October 5th, 1922.—The Third Session of the Fall Meeting was called to order at 10 A. M.; President John R. Freeman in the chair; John H. Dunlap, Secretary; and present, also, 346 members and guests.

In continuance of the Symposium on "The Water Power Problem", Frederick H. Fowler, Assoc. M. Am. Soc. C. E., presented a paper on "Water Power Potentialities of the Pacific Coast". Mr. Fowler was followed by John D. Galloway, M. Am. Soc. C. E., whose paper on "Hydro-Electric Developments on the Pacific Coast",† was illustrated with lantern slides.

These papers were followed by oral discussions of the subject by Messrs. J. D. Howells and M. M. O'Shaughnessy.‡

A paper by Mr. F. W. Peek, Jr., Consulting Engineer, General Electric Company, Pittsfield, Mass., entitled "High-Voltage Power Transmission",§ was presented by the author with the aid of lantern slides and a film. Mr. Peek was followed by Harris J. Ryan, Professor of Electrical Engineering, Leland Stanford Junior University, whose paper on "High-Voltage Phenomena Encountered in Power Transmission",¶ was also illustrated with lantern slides. These papers were followed by oral discussion of the subject by Mr. J. P. Jollyman.

A paper by H. W. Dennis, M. Am. Soc. C. E., and H. A. Barre, Executive Engineer, Southern California Edison Company, Los Angeles, Calif., entitled "Growth of the Use of Electric Power in Southern California and Probabilities of Its Future Growth with Reference to Sources of Hydraulic Power",‖ was presented by Mr. Dennis.

* See Papers and Discussions, p. 1824.

† *Loc. cit.*, p. 1846.

‡ *Loc. cit.*, p. 1879.

§ *Proceedings*, Am. Soc. C. E., November, 1922, p. 1766.

¶ See Papers and Discussions, p. 1859.

‖ *Loc. cit.*, p. 1865.

In the absence of Charles F. Loweth, M. Am. Soc. C. E., Secretary Dunlap presented the conclusions of his paper entitled "Hydro-Electric Power Development as Related to Electrification of Railroads".*

Announcements relative to badges, registration, etc., were made by Thomas H. Means, M. Am. Soc. C. E., of the Local Committee on Arrangements, and by Secretary Dunlap.

Adjourned.

EXCURSIONS AND ENTERTAINMENTS

SAN FRANCISCO, CALIF., MEETING

The arrangements for the Fall Meeting were made by a Local Committee, consisting of Messrs. A. H. Markwart, *Chairman,* E. C. Hutchinson, and F. H. Tibbetts. With this beginning, a much larger General Committee was organized, and numerous Sub-Committees were appointed, to make the meeting a success. The Sub-Committees consisted of the following:

Excursions.—Messrs. F. H. Fowler, *Chairman,* J. M. Owens, and G. H. Binkley, assisted by Mr. N. A. Eckart.

Registration and Information.—Messrs. R. A. Monroe, *Chairman,* and Lee O. Murphy, assisted by Messrs. H. V. Lutge, J. Burkhead, and Roy Cook, and Mrs. Charles W. Jackson.

Publicity.—Mr. Nathan A. Bowers, *Chairman,* with details by Mr. Howard Hanvey of the Publicity Organization.

Dinners.—Mr. E. B. Bumsted.

Ladies Entertainment.—Miss Clotilde Grunsky.

A very effective system was developed for handling the work of registration. Four attendants, provided by the Local Section, were at Registration Headquarters daily, and decisions about trips and the dissemination of information generally was aided by fourteen pieces of circular and descriptive matter for distribution, as follows:

A booklet† containing general information for members and guests (San Francisco Section); booklet on the Yosemite Valley (National Park Service); "Greeter's Guide of San Francisco" for September, 1922; "California Development", August, 1922 (California Development Association); map† showing transmission lines in California (Pacific Gas and Electric Company); The Peninsular Excursion Automobile Road Map† (California Automobile Association); "Aims and Activities of the American Society of Civil Engineers" (Parent Society); *Pacific Service Magazine* for September, 1922 (Pacific Gas and Electric Company); *General Electric Review*†, reprint of issue of March, 1922, containing two articles, "The Future Power Demand of California" and "Financing the Biggest Job Facing California"; reprint† from *Journal of Electricity and Western Industry,* descriptive of Pit River Project, a folder† of information on the Hetch Hetchy Project (M. M. O'Shaughnessy, M. Am. Soc. C. E.); maps† for the Don Pedro trip, and general information on the Don Pedro Development; list of registrations†; reprint of article† from *Engineering News-Record* of September 21st, 1922, on Hetch Hetchy Dam.

Dinner for Board of Direction.—On Tuesday evening, October 3d, the San Francisco Section gave a dinner to the members of the Board of Direction,

* See Papers and Discussions, p. 1872.

† Printed especially for the Fall Meeting.

which was attended by 54 members and guests. Mr. A. H. Markwart, Chairman of the Local Committee on Arrangements, acted as Toastmaster and called for brief talks from President John R. Freeman, Past-Presidents George H. Pegram, A. N. Talbot, and Arthur P. Davis, and Messrs. C. Derleth, Jr., and M. M. O'Shaughnessy.

Peninsula Automobile Excursion.—For Wednesday afternoon, October 4th, the Committee on Arrangements had planned an automobile excursion for the visitors. Thirty members of the San Francisco Section brought their automobiles to the Palace Hotel at 2 P. M., providing ample room for the 176 guests who took the trip. This excursion covered about 100 miles in San Francisco and vicinity. The route lay past points of interest in the city, such as Twin Peaks Tunnel, the summit of Twin Peaks, the ocean boulevard, Golden Gate Park, thence down the San Francisco Peninsula, through the suburban towns and past the Spring Valley Lakes, to Pulgas Tunnel, and, finally, to Leland Stanford Junior University, where a welcome by the Faculty and light refreshments in charge of the Student Chapter awaited the visitors. The party returned to the Palace Hotel in time for the evening program.

Entertainment for the Ladies.—While the meetings were in session, the wives of the members in attendance were entertained by a committee of ladies representing the San Francisco Section. Individuals and small groups were taken on shopping tours, visits to Chinatown, the Cliff House, the campus of the University of California, and other near-by points of interest. To Miss Clotilde Grunsky, as Chairman, and to the friends assisting her, the ladies owe a great debt of gratitude.

Mt. Tamalpais Trip.—The excursion on Thursday afternoon, October 5th, consisted of a trip up Mt. Tamalpais, *via* boat across the Golden Gate to Sausalito, and thence by train to the top of the mountain. The weather was fine and the party of 68 enjoyed a delightful outing, returning to the Palace Hotel in time for the Dinner and the Smoker.

Dinner and Smoker.—The dinner and smoker on Thursday evening was attended by 313 members and guests. President John R. Freeman acted as Toastmaster, and a paper* by Charles D. Marx, Past-President, Am. Soc. C. E., entitled "Social and Economic Aspects of Hydro-Electric Power", was presented by the author. Short addresses were made by Messrs. George G. Anderson, C. E. Grunsky, and John A. Britton. The meeting adjourned shortly after 10 P. M., in time for those in attendance to take the special train for the Hetch Hetchy Excursion, leaving at 11 P. M.

Hetch Hetchy Excursion.—Only 126 members and guests could be accommodated on the Hetch Hetchy Excursion, but more than this number had registered for the trip. It was possible to make this excursion between Thursday evening, October 5th, and Sunday morning, October 8th, by the use of a special Santa Fé train and the right of way not only along the Hetch Hetchy Railroad, but also over the various features of the project. The work on the dams, tunnels, power houses, penstocks, etc., was at the height of construction activity. The fact that several of the early pioneers on the Hetch Hetchy

* *Proceedings*, Am. Soc. C. E., November, 1922, p. 1781.

Project, namely, Messrs. Freeman, Grunsky, Marx, and Greene, were among the visitors, added interest, particularly to the after-dinner talks by Mr. O'Shaughnessy and others, on the purpose and progress of the work.

The mountain scenery and the long rides through the forests in perfect October weather combined to make an ideal outing. The guests obtained a true conception of the magnitude of the work when they made trips into the tunnels on flat-cars, were lowered on a skip from an overhead cableway into the canyon where the dam is under construction, and otherwise came into close personal touch with the diversified activities. The thrill of the trip, however, was the 3 500-ft. ride down Early Intake Incline which drops 1 700 ft., with a maximum slope of 88 per cent.

On Saturday afternoon, October 7th, when 22 members separated from the main Hetch Hetchy party at Mather, to start on the side trip to Yosemite, there was prolonged cheering and a degree of enthusiasm that marked this excursion as a fitting climax to one of the most successful meetings in the history of the Society.

Attendance.—There were 325 members of the Society in attendance at the Fall Meeting. In addition, ladies, guests, and members of Student Chapters increased the registration to 633. The students in attendance included 113 members of the Student Chapter of the Society at the University of California, and 20 members of the Student Chapter at Leland Stanford Junior University.

ADDRESS OF WELCOME AT THE FALL MEETING OF THE SOCIETY, SAN FRANCISCO, CALIF., OCTOBER 4TH, 1922

By John A. Britton,* Affiliate, Am. Soc. C. E.

Mr. Chairman and Members of the American Society of Civil Engineers: On behalf of the State of California, and particularly the City of San Francisco, I bid you a most hearty and cordial welcome. In your travels within this State, you will find evidences of the work accomplished by your predecessors. You will find much yet to be done of that character and type of work that you, as the pioneers of civilization, will notice.

About the time the American Society of Civil Engineers came into existence, some 70 years ago, this State was a mecca for those seeking only to wrest from its soil the gold which had been hidden there for ages. In that search for gold, the skill of those men in constructive engineering was shown. To them, the mountains had no terrors; gorges, gouged out by the ancient glaciers, were places for the conservation of water; granite cliffs and deep canyons were places for the construction of flumes and ditches. To-day, from the summit of the Sierras to the fertile valleys, works of that character exist, which bear the lasting impress of the skill and science exhibited by the civil engineers of those days.

During the last 70 years, many changes have occurred. From the days of the red-shirted miner, the care-free and pleasure-loving population, has come a change to a stable, reliable, energetic, and forceful people, and the days of gold have been forgotten. The days of constructive engineering have taken their place, and although much has been done for which Californians are proud, much more remains to be done. Engineers are needed now, and will always be needed, for the fuller development of the great possibilities of the future of California.

Civil Engineering originally embraced all classes of engineering, until civilization, in its marvelous growth, demanded specialization. Therefore, as civil engineers, you will, I am sure, be interested in a brief recital of developments in this State. Owing to the long period of drought after the run-off of the snows of the Sierras has taken place, particular attention has had to be given to the construction of dams for the conservation of flood waters, and to the construction of reservoirs for the establishment of permanent water supplies to the rapidly growing cities and towns.

Although the old days of hydraulic mining have passed, the soil in the foot-hills still holds untold measures of gold, and, to-day, great gold dredges are in operation. In the bridges spanning the canyons, and in the construction of highways, and in the railroads through the mountains, are reflected examples of engineering unequaled anywhere. Last, but by no means least, in hydro-electric development, this State leads the world. In the City of San Francisco, the first central station was constructed and placed in operation, generating electrical energy by steam power.

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* Vice-Pres. and Gen. Mgr., Pacific Gas & Elec. Co., San Francisco, Calif.

The first hydro-electric plant for commercial purposes was placed in service in this State, also the first long-distance, high-tension, transmission line and the longest high-voltage submarine cables. Until recently, we received credit for the largest span of aerial cables carrying high-tension energy; and we possess the most powerful single discharge turbine and the most powerful high-head water turbine in the world.

Time will not permit further detail of the engineering accomplishments in this State. Therefore, to this land of promise, endeavor, and accomplishment, to this city undaunted by fire and by earthquake, rising superior to it, to the greater accomplishments in the Panama-Pacific International Exposition, to the contribution of men and money to the winning of the World War, this State stands supreme. It presents the greatest possibilities for the studies of the problems of power, transportation, and industry, which will be a lodestone to attract the best in the minds of engineers. Welcome, therefore, to this city, and may your pleasure and profit in this visit exceed your utmost expectations.

REPLY TO ADDRESS OF WELCOME AT THE FALL MEETING OF THE SOCIETY, SAN FRANCISCO, CALIF., OCTOBER 4TH, 1922

By John R. Freeman, President, Am. Soc. C. E.

Mr. Britton, I want to say that we appreciate your words of welcome. I might add that we are inspired and look forward to the joy of this meeting. I am no stranger to your city; I have made many trips here, and I am frank to confess that when I first became acquainted with your delightful shores, I always felt and maintained the idea that, ultimately, this city might be my home. I think the same thought is held by every one here. We not only are much impressed with the natural beauties of this great State, its climate, vision, and inspiration, but also with the dominant and aggressive spirit of its people.

I was forcibly impressed, as Mr. Britton was speaking, with the pioneer work done in this State of which we are all the beneficiaries, the great pioneers, and particularly their energy and courage. I have only to mention a few developments, such as the Pelton water wheel, the San Mateo Bend, the first of the large concrete structures, the railroads, the civic center, and many other highly developed points in this State wherein you have the good fortune to dwell. Nowhere has such foresight and ingenuity been shown and displayed as that by the early pioneers in the effective and beneficial work on steel pipes. I remember that Clemens Herschel, Past-President, Am. Soc. C. E., who was the first to have charge of the building of the water-works of the East Jersey Company, asked permission of the Board of Directors to make a trip to California in order to study the methods and practice in vogue in regard to steel pipes, especially the emergency factors of safety pertaining thereto and the benefits to be derived if only the conditions were carefully studied. Throughout the pioneer work of the Profession, the remarkable

minds of your workers have demonstrated what they could do, for which we are all your debtors.

I was much impressed on the visit to the Pit River Power Plant, in thinking of the developmment of power during my own short life. It is now nearly fifty years since the engineers of one of the water power companies in New England installed what was then considered to be the largest water power project. In those days, Lowell and Lawrence, Mass., were great water power centers. In fact, they were the greatest water power centers in the world, having 150 turbines, which, altogether, developed about 30 000 h. p. The single unit which the Pacific Gas and Electric Company started in operation, at Pit River on September 30th, 1922, develops more power than the 150 turbines, combined, of Lowell and Lawrence. In showing the advancement and progress in engineering, the development of the water-power problems, the bringing of those great powers to mankind, it was interesting to hear the statement that that great plant would be cared for by only three men, which is in contrast to the great number required on each shift, for the 150 turbines previously mentioned. I also think that in your transmission lines, and in many matters which the engineer has to supervise and build, you have been the pioneers and have demonstrated what courage and energy might do for the sake of mankind.

The topic for discussion at this meeting, appropriately, has been taken as "The Water Power Problem". I think that one of the most eloquent and instructive addresses, by a President of the Society, that I ever heard, was that made by the late George S. Morison about thirty years ago.* In a philosophic vein, he traced the growth in manufacture and industry, primarily, to the development of water power and its allied and contributory advantages placed in the hands of mankind throughout the world. There is available some interesting statistics and facts on that subject. The design of the great plant which was recently visited—the Pit River Power Plant—and the important relation which that plant bears to civilization and progress, and the horsepowers per unit which forcibly tended to bring to mind its great possibilities, makes one realize what can be done for industries when they are supplied with modern equipment. Again, in considering this modern service, I could not help but think also of conditions as I observed them in China and Korea, where the power of man served for manufacturing and industrial activities, of men turning rice mills and towing boats, and of that unnecessary waste of human energy that might better be turned into other channels.

I am sure we shall all learn a great deal at this meeting and I think I can state that engineers already have learned a great deal from your practices in water power development. Perhaps you will be interested to know that with the exception of New York State, California has more members of the American Society of Civil Engineers than any other State.

We thank you, Mr. Britton, for this sincere and hearty welcome, and, in closing, I might say, particularly to these young men, that I have had the pleasure of your acquaintance for many years and have learned much about

* *Transactions,* Am. Soc. C. E., Vol. XXXIII (1895), p. 467.

your work. I believe that no man in the United States can look back on a prouder record of the confidence of his fellow men and of the loyalty of his whole organization, the Pacific Gas and Electric Company. I have been much touched with what I have heard in past years and the confidence with which the whole public regards the spirit, endeavor, and effort of that great public corporation.

MINUTES OF MEETINGS OF SPECIAL COMMITTEES TO REPORT ON ENGINEERING SUBJECTS

Special Committee on Irrigation Hydraulics

(Abstract)

October 4th and 5th, 1922.—Meetings of the Special Committee on Irrigation Hydraulics were held at the Engineers Club, San Francisco, Calif., on October 4th and 5th, 1922. Present, D. C. Henny (Chairman), Samuel Fortier, B. A. Etcheverry, Franklin Thomas, Stuart Sims, J. C. Stevens, and Fred C. Scobey.

On motion, duly seconded, Mr. Stevens was chosen as Secretary.

During an informal discussion, Mr. Henny outlined the research work that was being carried on by the U. S. Reclamation Service, and suggested that close co-operation should exist between the work of the Committee and that of Government and State agencies. Mr. Fortier outlined the work of the U. S. Department of Agriculture, in the investigation of silts in the Colorado, Rio Grande, and other southwestern streams, flow of water in steel pipes and flumes, etc. Professor Thomas discussed the needs of Southern California with regard to surface and underground storage, and Mr. Stevens mentioned the need of data regarding conversion losses in conduits and outlined a plan of laboratory experiments to determine the physical laws governing such losses. Professor Sims offered the use of the hydraulic laboratory at Corvallis, Calif., for the experiments outlined by Mr. Stevens.

As a result of this meeting, it was decided:

1.—That Messrs. Stevens and Sims outline to the Committee a definite plan for their proposed experiments on conversion losses and the laboratory facilities for carrying out such experiments.

2.—That each member send to the Chairman by November 1st, 1922, a list of definite subjects for investigation, that should be undertaken by the Committee and state those in which he is prepared to assist.

3.—That a bibliography of experimental data be prepared on the following subjects: (*a*) Evaporation losses from reservoirs; (*b*) conversion losses in open conduits; (*c*) silt problems in diversion works and irrigation canals; (*d*) uplift under masonry dams; (*e*) movement and pressure of water under dams and other irrigation structures on porous foundations; (*f*) hydraulics of chutes and drops; (*g*) coefficient of discharge of head-gate structures with all gates fully opened; (*h*) efficiency of siphon spillways; (*i*) means of measuring irrigation deliveries; and (*j*) effectiveness of linings in the prevention of seepage losses from irrigation canals.

4.—In order to prepare a bibliography on these subjects, the work was divided, the members of the Committee agreeing to list and prepare brief abstracts of articles on these subjects as follows: Publications of the U. S. Department of Agriculture, by Mr. Fortier; publications of the U. S. Reclamation Service and U. S. Geological Survey, by Messrs. Henny and Savage; college publications and experiment station bulletins, by Professor Sims; *Minutes of Proceedings* of the Institution of Civil Engineers, the *Transactions* of the Society, and *Engineering* (London), by Professor Thomas; India papers,

French publications, and textbooks, by Professor Etcheverry; *Engineering News-Record,* by Mr. Stevens; and a complete bibliography on the flow of water in steel pipes, by Mr. Scobey.

5.—Those members who were not present at the meeting are to advise the Committee promptly in what part of the work, as outlined, they are prepared to assist.

The meeting was adjourned subject to the call of the Chairman.

Special Committee on Bridge Design and Construction

(Abstract)

October 6th and 7th, 1922.—The meetings were called to order at the Headquarters of the Society. Present: H. B. Seaman (Chairman), J. H. Ames, V. H. Cochrane, O. E. Hovey, E. F. Kelley, S. B. Slack, and C. R. Harding (Secretary).

On motion, duly seconded, Mr. C. R. Harding was elected Secretary of the Committee to succeed Mr. H. C. Baird, resigned.

On motion, duly seconded, the following resolution was adopted:

"That the Standard Specifications for Structural Steel for Bridges, Serial Designation A-7-21, and the Standard Specifications for Structural Nickel Steel, Serial Designation A-8-21, of the American Society for Testing Materials be adopted by this Committee".

Mr. Hovey presented a draft of specifications for Section 5, Workmanship; Section 6, Shop Inspection; Section 7, Full Size Eye-Bar Tests; and Section 8, Weighing and Shipping, which were prepared by a Sub-Committee composed of Messrs. Hovey and J. E. Greiner. On motion, duly seconded, these specifications were adopted by the Committee with various changes.

Section A, General; Section 1, Loads and Stresses; Section 2, Unit Stresses; and Section 3, Details of Design, as modified at the June, 1922, meeting of the Committee, were presented for reconsideration by the Secretary, and, on motion, duly seconded, were adopted with various changes.

Mr. Kelley, for the Sub-Committee composed of himself and Professor M. S. Ketchum, presented a section on Live Loads for the Tentative Specifications for Steel Highway and Electric Railway Bridges, and, on motion, duly seconded, these Specifications were adopted by the Committee with changes.

On motion, duly seconded, it was unanimously decided that the Chairman be authorized to appoint a Sub-Committee to draft Sections on Materials and Workmanship for the Tentative Specifications for Steel Highway and Electric Railway Bridges. The Chairman subsequently appointed the following as members of this Sub-Committee: Messrs. E. F. Kelley, Chairman, J. H. Ames and S. B. Slack.

Special Committee to Codify Present Practice on the Bearing Value of Soils for Foundations, Etc.

(Abstract)

October 18th, 1922.—The meeting was called to order at 2 P. M., at the Headquarters of the Society. Present, Robert A. Cummings (Chairman), Allen Hazen, and J. C. Meem.

The minutes of the previous meeting were approved as submitted.

Mr. Meem reported progress on behalf of the Sub-Committee on Codification, and a letter from Mr. E. G. Haines on the same subject was also presented.

The work being conducted by the Iowa State College was discussed, as well as the work of the United States Bureau of Public Roads.

Mr. Meem urged that steps be taken to have full-size tests made under the auspices of the Committee, the desirability of which was agreed to, but the matter was deferred until ways and means could be found.

Mr. Cummings reported progress on the study of the colloidal state of clay.

A report on Land Slides by the Geotechnical Commission of the Royal State Railways of Sweden was presented. Copies of a thesis on "Lateral Earth Pressure" by Dr. J. Feld were also presented, and distributed for consideration by the members of the Committee.

A suggestion from a member of the Research Committee of the Society for an increase in the Committee membership, in order to give immediate consideration to important divisions of the work such as Piles and Pile Driving, Land Slides, etc., was considered. At the beginning of the Committee's investigation, sub-committees were organized, but their activities were suspended, pending a research study of soil itself. Inasmuch as the physical characteristics of soil have been brought to an understandable state, it was decided, on motion, duly seconded, that the Chairman communicate with the Board of Direction asking for an increase in the membership of the Committee to cover these subjects.

ANNOUNCEMENTS

The Reading Room of the Society is open from 9 A. M. to 6 P. M., and from 7 P. M. to 10 P. M., every day, except Sundays, New Year's Day, Washington's Birthday, Memorial Day, Fourth of July, Labor Day, Thanksgiving Day, and Christmas Day; during July and August, it is closed at 5 P. M.

FUTURE MEETINGS

December 20th, 1922.—8.00 P. M.—A regular business meeting of the Society will be held, the program for which will be announced later.

ANNUAL MEETING

The Seventieth Annual Meeting will be held at the Headquarters of the Society, 33 West 39th Street, New York City, on Wednesday, Thursday, and Friday, January 17th, 18th, and 19th, 1923.

SEARCHES IN THE LIBRARY

As the Library of the American Society of Civil Engineers has been merged in the Engineering Societies Library, requests for searches, copies, translations, etc., should be addressed to the Director, Engineering Societies Library, 29 West 39th Street, New York City, who will gladly give information concerning the charges for the various kinds of service. A more comprehensive statement in regard to this matter will be found on page 26 of the Year Book for 1922.

NEW LOCAL SECTIONS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

The Constitutions of the following Local Sections have been approved by the Board of Direction since the list was prepared for the 1922 Year Book, pp. 41 *et seq.:*

Dayton Section (Constitution Approved by Board, 1922).

Charles H. Paul, President; K. C. Grant, Secretary-Treasurer, Winters Bank Building, Dayton, Ohio.

Lehigh Valley Section (Constitution Approved by Board, 1922).

George H. Blakeley, President; M. O. Fuller, Secretary-Treasurer, 732 Avenue H, Bethlehem, Pa.

Sacramento Section (Constitution Approved by Board, 1922).

Albert Givan, President; Joseph W. Gross, Secretary, Forum Building, Sacramento, Calif.

Toledo Section (Constitution Approved by Board, 1922).

M. J. Riggs, President; George N. Schoonmaker, Secretary-Treasurer, 716 Stickney Avenue, Toledo, Ohio.

Virginia Section (Constitution Approved by Board, 1922).

J. C. Carpenter, President; James F. MacTier, Secretary-Treasurer, 1312 Maple Avenue, Roanoke, Va.

NEW STUDENT CHAPTERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS*

The following Student Chapters have been authorized by the Board of Direction since the list was prepared for the 1922 Year Book, pp. 46 *et seq.:*

Clemson Agricultural and Mechanical College of South Carolina.

J. H. Baumann, President; W. J. Stribling, Secretary, Clemson Agricultural and Mechanical College of South Carolina, Clemson College, S. C.

Georgia School of Technology.

F. H. Harrison, President; C. M. Kennedy, Jr., Secretary, 91 West North Avenue, Atlanta, Ga.

Lehigh University.

H. S. Ertner, President; J. H. Van Ness, Secretary, 223 Summit Street, Bethlehem, Pa.

North Carolina State College of Agriculture and Engineering.

H. L. Fisher, President; A. S. Gay, Secretary, North Carolina State College, Raleigh, N. C.

Norwich University.

J. H. Kane, President; Allen J. Hamilton, Secretary, Norwich University, Northfield, Vt.

Stadia Club (University of Oklahoma).

Lester W. Ellis, President; Edward W. Mars, Secretary, University of Oklahoma, 734 DeBarr Street, Norman, Okla.

University of Virginia.

T. B. Kiener, Secretary, Box 423, University, Va.

Worcester Polytechnic Institute.

Carl F. Meyer, President; Albert P. Hayden, Secretary, Worcester Polytechnic Institute, Worcester, Mass.

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* By a recent ruling of the Board of Direction, the minimum membership of a Student Chapter has been fixed at 12 instead of 20.

MEMBERSHIP

(From October 4th to October 27th, 1922)

ADDITIONS

MEMBERS

Members	Grade	Date of Membership.
ANDREW, CHARLES EDWARD. Bridge Engr., State of Washington, Mitchell Hotel, Apartment 7, Olympia, Wash.		June 19, 1922
BARTOW, EDWARD. Prof. and Head, Dept. of Chemistry, State Univ. of Iowa, 101 Close Hall, Iowa City, Iowa		Oct. 2, 1922
BURKHOLDER, JOSEPH L. Care, The Barahona Co., Inc., Barahona, Dominican Republic	Assoc. M. M.	Sept. 3, 1913 Aug. 28, 1922
CHEVALIER, WILLARD TOWNSHEND. Associate Editor, *Engineering News-Record*, 10th Ave. and 36th St., New York City	Jun. Assoc. M. M.	April 6, 1909 April 30, 1912 Oct. 3, 1922
CRAGO, WILLIAM HENRY. Cons. Min. Engr., 307 First National Bank Bldg., Duluth, Minn.		Oct. 2, 1922
DOUGHERTY, HENRY MICHAEL. Chf. Engr., Chile Exploration Co., Chuquicamata, Chile	Assoc. M. M.	May 6, 1908 May 8, 1922
DUCKERING, WILLIAM ELMHIRST. Prof., Eng. Problems, Iowa State Coll., Ames, Iowa		Aug. 28, 1922
EDWARDS, GEORGE GARRETT. Engr., Ellis County Road Dist. No. 3, Box 265, Ennis, Tex.	Assoc. M. M.	Dec. 6, 1915 Oct. 3, 1922
ELSPASS, GEORGE WARREN. With The Graselli Chemical Co., Cleveland (Res., 1581 Belle Ave., Lakewood), Ohio		Oct. 2, 1922
FEELEY, WILLIAM PATRICK. Div. Engr., Buffalo Dist., Great Lakes Dredge & Dock Co., 1100 Morgan Bldg., Buffalo, N. Y.	Jun. Assoc. M. M.	May 2, 1911 Nov. 4, 1914 June 20, 1922
FOULKS, JOHN AUBREY. Chf. Engr., Div. of Water, City of Newark, City Hall, Newark (Res., 93 Mercer Ave., North Plainfield), N. J.		Oct. 2, 1922
GILMAN, EDGAR DOW. Asst. Prof. of Civ. Eng., Univ. of Cincinnati, Cincinnati, Ohio	Jun. Assoc. M. M.	April 1, 1914 Sept. 12, 1916 Oct. 3, 1922
GOODWIN, WILLIAM ROBERT. Engr., Timber Preservation, Soo Line Ry., 1517 Soo Bldg. (Res., 2552 Aldrich Ave. South), Minneapolis, Minn.	Assoc. M. M.	May 15, 1917 Oct. 3, 1922
GRANDLIENARD, EDWARD THEODORE. Asst. Prof., Civ. Eng., Univ. of Pennsylvania, Philadelphia, Pa.		Oct. 2, 1922
GRUNSKY, CARL EWALD, JR. Cons. Engr. (C. E. Grunsky Co.), 57 Post St., San Francisco, Calif.		June 19, 1922
HARVEY, JAMES CAROTHERS. Contr. (French & Harvey), Santa Fé, N. Mex.	Assoc. M. M.	Sept. 10, 1918 Oct. 3, 1922
HEBBLEWHITE, GILBERT WALTER. Chf. Engr., International Steel & Iron Co., 1228 Chandler Ave., Evansville, Ind.		Oct. 2, 1922
JACOBY, HENRY SYLVESTER. Prof. Emeritus, Bridge Eng., Coll. of Eng., Cornell Univ., 201 Fairmount Ave., Ithaca, N. Y.	Affiliate M.	Nov. 5, 1890 Oct. 3, 1922
LEEFERS, OTIS LEON. Cons. Engr. and Insp., Board of Education, 1801 Fourth Ave., Cedar Rapids, Iowa		Oct. 2, 1922

MEMBERS—(*Continued*)

		Date of Membership.
LEWIS, HAROLD MACLEAN. Executive Engr., Russell Sage Foundation, 130 East 22d St., New York City (Res., 114 Twenty-first St., Elmhurst, N. Y.)	Jun. Assoc. M. M.	Feb. 4, 1913 Nov. 28, 1916 Oct. 3, 1922
LONG, JAMES BLAIR. Civ. and Const. Engr., 59 Boyer Arcade, Norristown, Pa.	Assoc. M. M.	Jan. 13, 1919 Oct. 3, 1922
MCCALMAN, DONALD SMITH. Engr. and Contr., 414 East 23d St., Cheyenne, Wyo.		June 19, 1922
MANN, CLAIR VICTOR. Head, Dept. of Eng. Drawing, Missouri School of Mines and Metallurgy, Box 39, Rolla, Mo.		Oct. 2, 1922
MAYER, LEWIS CHRISTIAN. Chf. Engr. and Vice-Pres., York Rys., 27 West Market St., York, Pa.		Oct. 2, 1922
MEHREN, EDWARD JOHN. Editor, *Engineering News-Record*, 10th Ave. and 36th St., New York City	Jun. Affiliate M.	Oct. 30, 1906 Jan. 7, 1913 Oct. 3, 1922
MOREY, EUGENE HENRY. Chf., Bureau of Roads and Bridges, State of Nebraska, 1834 Perkins Boulevard, Lincoln, Nebr.		Oct. 2, 1922
PRESTON, HARRY LONGYEAR. Asst. Engr., Valuation Dept., N. Y. C. R. R., Room 3754, Grand Central Terminal, New York City	Assoc. M. M.	April 1, 1908 Oct. 3, 1922
PUTNAM, CHARLTON DASCOM. Civ. and Landscape Engr., 1010 Schwind Bldg., Dayton, Ohio		Aug. 28, 1922
REVELL, JOHN. City Engr. and Asst. Commr. of Works, Fort Collins, Colo.	Assoc. M. M.	Nov. 27, 1917 Oct. 3, 1922
SAUERBRUN, ALFRED HUMMEL. Care, Societa Anonima Italiana MacArthur, Via Onorato, No. 9, Palermo, Sicily		Aug. 28, 1922
SMITH, JULIAN CLEVELAND. Vice-Pres. and Gen. Mgr., Shawinigan Cos., 314 Lansdowne Ave., Westmount, Montreal, Que., Canada		Oct. 2, 1922
SPURR, HENRY VOSE. Chf. Engr., Purdy & Henderson Co., 45 East 17th St., New York City		Aug. 28, 1922
THOMSON, LESSLIE RIELLE. Secy., Lignite Utilization Board, 288 St. James St., Montreal, Que., Canada.	Assoc. M. M.	Dec. 2, 1914 Oct. 3, 1922
TONER, ARTHUR CARLING. Dist. Engr., Portland Cement Assoc., 1904 Farmers Bank Bldg., Pittsburgh, Pa.	Assoc. M. M.	Oct. 1, 1912 Oct. 3, 1922
TOYNE, JOHN WILSON. Farmers Trust Bldg., South Bend, Ind.	Assoc. M. M.	Nov. 28, 1916 Oct. 3, 1922
WILEY, RALPH BENJAMIN. Prof., San. Eng., Purdue Univ., 777 Russell St., West Lafayette, Ind.	Jun. Assoc. M. M.	Feb. 4, 1908 May 31, 1916 Oct. 3, 1922
WILLIAMSON, ORA KILBURN. County Engr., Wyandotte County, and Res. Engr. for State on Federal Projects, Edwardsville, Kans.		Oct. 2, 1922

ASSOCIATE MEMBERS

AIKEN, WILLIAM DREES. Asst. Engr., Office of Engr. of Structures, N. Y. C. R. R., 51 Barry Ave., Mamaroneck, N. Y.	Aug. 28, 1922
ALDRICH, ELLWOOD HARMON. City Engr., Wisconsin Rapids, Wis.	Oct. 2, 1922
AYDLOTTE, ROSWELL JAMES. County Engr., Delaware County, 515 Parker St., Chester, Pa.	Oct. 2, 1922

ASSOCIATE MEMBERS—(*Continued*)		Date of Membership.
BAILEY, JOHN SAMUEL. Constr. Engr., Portland Cement Assoc., 1321 Hurt Bldg., Atlanta, Ga		Oct. 2, 1922
BAKER, GEORGE FARNSWORTH. Camp Dudley, Westport, N. Y		Oct. 2, 1922
BARTH, IRA STEINER. 601 Commercial St., Atchison, Kans		Oct. 2, 1922
BAUER, OWEN W. Hydrographer, Southern California Edison Co. (Res., 4511 Finley Ave.), Los Angeles, Calif		Oct. 2, 1922
CHANEY, CHARLES ATWELL. Div. Engr. of Bridges, City of Pittsburgh, 6410 Phillips Ave., Pittsburgh, Pa		Oct. 2, 1922
CONZELMAN, JOSEPH HARRISON. Mgr., Birmingham Office, Pittsburgh Testing Laboratory, 216 Clark Bldg., Birmingham, Ala.		Oct. 2, 1922
DAVIS, ARTHUR BOYD. Contr. Engr., Virginia Bridge & Iron Co., Box 785, New Orleans, La		Oct. 2, 1922
ERIKSSON, ERIK JOSEPH. Civ. Engr., Minnesota Steel Co., 5603 West 8th St., West Duluth, Minn		Oct. 2, 1922
FRERE, WILLIAM JOSEPH, JR. Res. Engr., Iowa Highway Comm., 1020 Fourth Ave., Council Bluffs, Iowa		Oct. 2, 1922
GREER, CLINTON MERRITT. Designer and Asst. Bridge Engr., St. Louis County, 212 Court House, Duluth, Minn		Oct. 2, 1922
HANAUER, HERBERT WILLIAM. Director of Works, Egyptian Ministry of Public Works, rue Mamelukes, Heliopolis, Egypt.		Aug. 28, 1922
HART, WALTER EDWIN. Mgr., Structural Bureau, Portland Cement Assoc., 111 West Washington St., Chicago, Ill		Oct. 2, 1922
HELMICK, DANIEL STORMS. 1200 Second Ave., South, Minneapolis, Minn.		Aug. 28, 1922
JEWELL, JOSEPH BARNARD. Field and Constr. Engr., Oakland County Road Commrs., 483 Orchard Lake Ave., Pontiac, Mich.		Oct. 2, 1922
KENNEDY, THOMAS B., JR. Engr., The Frog, Switch & Mfg. Co., Carlisle, Pa		Oct. 2, 1922
KURZ, ERNST WILLIAM. 805 East State St., Ithaca, N. Y		Oct. 2, 1922
LEWIS, JAMES ARTEMUS. With Miller & Martin, 910 Title Guarantee Bldg., Birmingham, Ala		Oct. 2, 1922
LLOYD, GEORGE TAYLOR. Chf. Engr., Florida Farms & Industries Co., Box 387, Green Cove Springs, Fla		Aug. 28, 1922
MAIER, EDWARD HELLER. Civ. Engr. and Surv., 51 North Pearl St., Bridgeton, N. J		Oct. 2, 1922
MITCHELL, WILLIAM NORMAN. 4967 Lake Park Ave., Chicago, Ill.		Oct. 2, 1922
PADDOCK, EUGENE HIRAM. 74 Robertson Ave., White Plains, N. Y.		Oct. 2, 1922
RAMP, WILLIAM HAROLD. County Road Engr., Wetzel County Road Dept., New Martinsville, W. Va		Oct. 2, 1922
RASCH, CHARLES JOHN. Engr. Examiner, U. S. Shipping Board, Emergency Fleet Corporation, 2846 Guilford Ave., Baltimore, Md		Oct. 2, 1922
SCUDDER, CHARLES MORRISON. Asst. Engr., Hydr. Turbine Dept., Allis Chalmers Mfg. Co., Milwaukee (Res., 239 Sixth Ave., Wauwatosa), Wis	Jun. Assoc. M.	May 28, 1912 Oct. 2, 1922
SHOOK, CHARLES HARMON. Designing and Contr. Engr., 1010 Schwind Bldg., Dayton, Ohio		Oct. 2, 1922
SMITH, MORTIMER WILSON, JR. Asst. City Engr., 437 West Main St., Clarksburg, W. Va		Oct. 2, 1922

ASSOCIATE MEMBERS—(*Continued*)		Date of Membership.
SNOW, BAYARD FRANCIS. Chf. Engr., African Union Co., Inc., Secondee, Gold Coast, West Africa		Oct. 2, 1922
SNYDER, HOWARD HALSEY. Cons. Engr. (Ball & Snyder), 19 East 24th St., New York City		Oct. 2, 1922
SPOERER, EDWARD JOHN. Structural Engr. and Plan Examiner, Jersey City Bldg. Dept., 8 Webster Ave., Jersey City, N. J.		Oct. 2, 1922
STACKPOLE, DONALD CAMERON. Dist. Engr., Dist. No. 1, State Highway Dept., Bellefonte, Pa		Oct. 2, 1922
STANTON, WILLIAM LEWIS. Associate Prof., Civ. Eng., A. and M. Coll. of Texas, College Station, Tex.	Jun. Assoc. M.	June 11, 1917 Oct. 2, 1922
STEERE, MAYNARD JOSEPH. Res Engr., Gerharz-Jaqueth Eng. Co., Box 66, Radersburg, Mont		Oct. 2, 1922
STODDARD, WALTER EUGENE. Chf. Draftsman and Asst. Office Engr., Reclamation Board, State of California, 2036 Thirty-fourth St., Sacramento, Calif		Oct. 2, 1922
TIPTON, ROYCE JAY. Chf. Engr., San Luis Val. Land & Min. Co., Crestone, Colo		June 19, 1922
VAN EENENAAM, CORNELIUS. Chf. Draftsman, Bridge Office, Michigan State Highway Dept., 904 Dewey Ave., Ann Arbor, Mich	Jun. Assoc. M.	Mar. 11, 1919 Oct. 2, 1922
WHITE, AMBROSE MICHAEL. Dist. Engr., Pennsylvania State Highway Dept., Bedford, Pa		Oct. 2, 1922
YOUNG, SAMUEL ROLLO. Asst. Chf. Engr., A. & W. P. R. R., W. Ry. of A., and Ga. R. R., 4th Floor, Terminal Station, Atlanta, Ga		June 19, 1922

JUNIORS

BACKES, EDWARD WILLIAM. Monte No. 1, Havana, Cuba	Oct. 2, 1922
COHEN, SAM. 128 President St., Passaic, N. J	Oct. 2, 1922
CONE, GEORGE HUBERT. Estimator, McKenzie Constr. Co., 606 Bedell Bldg., San Antonio, Tex	Oct. 2, 1922
COSTELLO, EDWARD JAMES, JR. 2541 Oliver Bldg., Pittsburgh, Pa	Oct. 2, 1922
ESQUIVEL Y FRIAS, PRUDENCIO. 301 Bryant Ave., Ithaca, N. Y	Oct. 2, 1922
GARDNER, CURTISS TARRING. Material Insp. with N. Y., N. H. & H. R. R., 58 Plainfield St., Waban, Mass	Oct. 2, 1922
GERDES, HENRY GEORGE. 312 Church St., San Francisco, Calif	Oct. 2, 1922
GOMEZ RODRIGUEZ, CASIMIRO OSVALDO. Asst. Engr., Public Works Dept., O. P. Office, Care, José De Pool, Santo Domingo, Dominican Republic	April 3, 1922
HUDSON, FRANKLIN, JR. 3741 Bell St., Kansas City, Mo	Oct. 2, 1922
JOHNSON, JOEL MUNSON. Draftsman and Field Engr., Maracaibo (Venezuela) Oil Co., 108 Broadway, Bayonne, N. J	Oct. 2, 1922
MINER, GRANT LENOX, JR. (The Miner Co.), 2234 Macdonald Ave., Richmond, Calif	Oct. 2, 1922
OLSON, HERBERT AUGUSTUS. Asst. City Engr., Emporia, Kans	Oct. 2, 1922
SARVIS, ROBERT GUYLE FENTON. 8315 Curzon Ave., Cincinnati, Ohio.	Oct. 2, 1922
SMITH, WALTER SCHLEY. Junior Asst. Engr., U. S. Bureau of Public Roads, Box 25, Pineville, Ky	May 8, 1922
STERNS, JENO. 917 West Water St., Elmira, N. Y	Aug. 28, 1922

JUNIORS—(*Continued*)	Date of Membership.
STUPP, OSCAR CENTURY. Designing Concrete Engr., J. T. Craven Eng. Co., 3667 Utah Pl., St. Louis, Mo	Oct. 2, 1922
TROXELL, HAROLD COBLE. Junior Engr., U. S. Geological Survey, Water Resources Branch, 602 Federal Bldg., Los Angeles, Calif.	Oct. 2, 1922
WADDINGTON, ROBERT RAYMOND. Asst. to Chf. Dispatch Engr., Standard Oil Co., Marine Dept., 433 Linden Ave., Elizabeth, N. J.	Oct. 2, 1922

REINSTATEMENTS

ASSOCIATE MEMBERS	Date of Reinstatement.
BAKER, SHELDON KING	Oct. 3, 1922

DEATHS

CHAMBERLIN, CHESTER HARVEY. Elected Member, October 5th, 1904; died July 14th, 1922.

HASKINS, WILLIAM JEWETT. Elected Junior, March 7th, 1883; Member, December 1st, 1886; died October 9th, 1922.

MCCANN, THOMAS HENRY. Elected Member, April 2d, 1890; died October 25th, 1922.

WASHBURN, FRANK SHERMAN. Elected Member, November 7th, 1888; died October 9th, 1922.

Total Membership of the Society, October 27th, 1922

Members	4 655	
Associate Members	5 260	
Corporate Members		9 915
Honorary Members		11
Juniors		475
Affiliates		168
Fellows		10
Total		10 579

ENGINEERING SOCIETIES EMPLOYMENT SERVICE

An Engineering Societies Service Bureau was established December 1st, 1918, as an activity of Engineering Council. It was managed by a board made up of the Secretaries of the four Founder Societies, and funds for its maintenance were provided by these Societies. On January 1st, 1921, this Bureau was taken over by The Federated American Engineering Societies and was known as the Employment Service of that organization. Recently, the management of the Service has been taken over by the Founder Societies. A weekly Employment Bulletin, listing the positions available, may be seen at the office of any Secretary of a Local Section. Members of the American Society of Civil Engineers who desire to register should apply for further information, registration forms, etc., to Walter V. Brown, Manager, Engineering Societies Building, 29 West 39th Street, New York City. In order to be included in the list published in *Proceedings,* copy must be received on or before the first of each month. All communications should be addressed to Mr. Brown.

EMPLOYMENT BULLETIN

POSITIONS AVAILABLE

SALES ENGINEERS (4 or 5) to sell concrete mixers, saw rigs, cranes, etc. Expenses will be paid. Application in person. Headquarters, New York City. V–1649.

SALES MANAGER. Large manufacturer located in East-Central Section desires man familiar with sale of raw materials and primary products. Prefer man acquainted with steel and allied industries. Write fully stating experience and salary desired. Application by letter. Headquarters, Chicago, Ill. V–1653.

SALES ENGINEER, to sell industrial paint of unique qualities. Possibility of handling other interesting lines. Sales experience not necessary. Good proposition for recent graduate wishing to enter sales line. Application in person by appointment. Headquarters, New York City. V–2504.

SALES EXECUTIVE for well established firm of Engineers and Constructors in New York City. Must be a man of character and standing, with a wide acquaintance among business men and a talent and personality for sales. Assured future for right man. Application by letter giving full information. Salary not stated. Location, New York City. V–2510.

SALES REPRESENTATIVES to represent gas and oil-burning equipment company in United States. Application by letter. V–2513.

SALES ENGINEER, young, single man having 1 or 2 years' practical experience for exploiting sale of a line of industrial equipment in New England and Middle Atlantic States. Application by letter, stating age, experience, and salary expected. Headquarters, New York City. V–2517.

SALES ENGINEER to sell crushing and grinding machinery. Application in person. Location, New York City. V–2522.

ARCHITECTURAL DRAFTSMAN able to make working drawings, from sketches, any details necessary filing in city departments, etc. Application in person. Location, New York City. V–2546.

ENGINEER with advertising or catalogue writing experience. Application by letter, stating age, education, and experience in detail. Location, New York State. V–2548.

DRAFTSMAN DESIGNER, Civil Engineer, on structures, reinforced concrete. Must be good draftsman as well as designer. Application by letter. Location, New York City. V–2559.

SALES ENGINEER, preferably between 30 and 40 years of age, with experience in sale of foundry equipment, to act as district representative. Right man can make very profitable connection. Application by letter. Location, Cleveland, Ohio. V–2561.

DRAFTSMAN for sugar-mill. Prefer young man recently graduated from college or architectural or engineering school, who could be classed as good draftsman. Working knowledge of Spanish desirable. Application by letter. Transportation from New York to plantation. Headquarters, New York City. Location, Cuba. V–2580.

STRUCTURAL ENGINEER thoroughly trained in design of structural steel and reinforced concrete for buildings. One who can write specifications and attend to supervision preferred. Application by letter. Location, Arkansas. V–2581.

MINING ENGINEER familiar with mining of silica in all branches, to check report on property, purchase, install and operate equipment, etc. Application in person. Salary not stated. Location, Conn. V–2590.

YOUNG GRADUATE ENGINEER with a little building experience, to learn business from the office end. Estimate primarily. Application by letter. Location, New York City. V–2595.

ENGINEER experienced in road building and handling of crushed stone, to call on firms to investigate the market in Illinois with view of opening a lime quarry. Application by letter. Location, Illinois. V–2611.

INSPECTORS OF CONSTRUCTION (3) for Naval Station at Pearl Harbor. Subject to non-competitive examination. Application by letter. Headquarters, Washington, D. C. V–2614.

STRUCTURAL STEEL DRAFTSMAN experienced on ornamental and light steel work. Application in person. Location, Long Island, N. Y. V–2616.

DRAFTSMAN familiar with power plant, water supply, and architectural work. Must speak Spanish. Application by letter. Location, South America. V–2618.

ARCHITECT experienced in general design, office, industrial, and municipal buildings. Must speak Spanish. Application by letter. Location, South America. V–2619.

CHIEF DRAFTSMAN to take charge of drafting office. Must speak Spanish. Application by letter. Location, South America. V–2621.

COST ENGINEER experienced in general contracting cost work, also cost plus basis system for municipal work. Must be able to establish cost system for contractor's office. Spanish desirable. Application by letter. Location, South America. V–2622.

REINFORCED CONCRETE ENGINEER with wide experience on construction of reinforced concrete buildings. Temporary work (2 or 3 months), supervising building of forms and placing reinforcement. Application by letter. Location, Mass. V–2624.

DRAFTSMAN with water-wheel experience. Age between 35 and 45. Need not necessarily be a technical graduate. Application by letter. Location, Mass. V–2625.

ARCHITECT for remodeling and miscellaneous repairs to public buildings. Allowance for travel from New York and return. Knowledge of Spanish desirable, but not essential. Application in person by appointment. Location, Santo Domingo. V–2626.

CIVIL ENGINEER for road construction. Age 30 years. Spanish desirable, but not essential. Must be single. Experience desirable. Application in person by appointment. Location, Santo Domingo. V–2627.

ENGINEER with experience in manufacture of loose-leaf books. Manufacture of a pocket-book contemplated. Want man capable of starting necessary plant and taking charge of operations. Application by letter only. Location, Penna. V–2633.

ENGINEER to write articles dealing with economic, political, and social problems of the day. Must be capable of writing original articles that will interest intelligent people of all classes and secure attention of engineers, business men, educators, and statesmen. Application by letter only. Location, Penna. V–2634.

ENGINEERS capable of gathering information needed in different branches of engineering and putting it in most concise form for publication in bound books to be used in conjunction with loose-leaf service. Application by letter only. Location, Penna. V–2635.

SURVEYOR to take charge of a party and run his own instrument in general city work. Temporary position (2 to 3 months' work). Application by letter. Location, Mass. V–2636.

ARCHITECTURAL DRAFTSMAN experienced on frame buildings and country homes. Application in person. Location, Conn. V–2638.

STRUCTURAL STEEL DRAFTSMEN, OR DRAFTSMEN familiar with reinforced concrete work. Application by letter. Location, South Carolina. V–2639.

SALESMEN (2). Age 25 to 28. Will be sent to factory for course of training before going on road. Prefer unmarried men willing to live in some other city, either as District Manager or Assistant to District Manager. Application by letter. Headquarters, New York City. V–2641.

STREET RAILWAY ENGINEER, between 35 to 45 years of age, having had some technical education and a number of years practical experience in actual operation of all classes of street railway rolling stock. Application by letter giving education, experience, age, and salary desired. Location, New York City. V–2652.

STRUCTURAL DRAFTSMEN (10). Application by letter. Location, New York City. V–2654.

MANUFACTURER of Constant Potential Battery Charging Systems for Battery Service Stations, has several districts open for agencies and desires to hear from men experienced in sale of battery equipment and an acquaintance in the trade. Application by letter. Headquarters, Chicago, Ill. V–2660.

CHECKER AND DETAILER, A–1, for general structural and bridge work. Must be experienced, reliable and absolutely competent to handle any kind of work as outlined. Application by letter. Location, St. Louis, Mo. V–2665.

SALES REPRESENTATIVE: Trained correspondent and sales engineer. Graduate M. E. Broad experience. Progressive. Traveled Chicago, Indianapolis, and Cincinnati territories. Application by letter. Headquarters, Cincinnati, Ohio. V–2666.

EXPORT SALES REPRESENTATIVE for company manufacturing nestable culvert. Man representing other company who has his own office and would be interested to add other products to his present line, desired. Application in person. Salary not stated. Location not stated. V–2668.

PLATER experienced in continuous process of coating fine wire. Must have sufficient knowledge of chemistry to make own formulas. If applicant has executed experience there is an opportunity to become interested in the business. Application by letter. Location, Mass. V–2670.

STENOGRAPHER, Secretary and General Assistant to Manager of several electric light and water properties in New Jersey. Excellent position with unlimited field for advancement. Do not apply unless thoroughly experienced and competent. Male preferred, but not essential. Living conditions excellent. Application by letter. Location, New Jersey. V–2688.

CONTRACTORS or Qualified Engineers to go into the matter of cost of construction of tunnel underneath river which is 650 ft. wide, together with cost of approaches, etc. Application by letter. Salary not stated. Location, North Carolina. V–2693.

ENGINEER thoroughly experienced on railway and transmission line location to supervise and co-ordinate work of several field parties. Application by letter. Location, Central Penna. V–2702.

TRANSITMEN (2) to act as chief of party; must have experience on railroad or transmission line location. Application by letter. Location, Penna. V–2703.

SALES ENGINEER with experience, preferably in handling plant equipment, to sell heavy capacity scales. Application by letter. Location, New York City. V–2707.

ASSISTANT PLANT ENGINEER to handle some construction and experimental work. Application by letter. Location, New Jersey. V–2708.

EXPERIENCED ELECTRICAL LAYOUT DRAFTSMEN (2) familiar with both railway and commercial sub-station layouts. Permanent position. Application by letter. Location, Georgia. V–2709.

SALES ENGINEER. Reliable company located in East wishes the services of a competent sales engineer to organize and develop an organization for marketing its line of internal combustion engines. Do not apply unless you can produce results. Application by letter. Headquarters, New York State. V–2714.

POWER PLANT ENGINEER AND MAINTENANCE MAN, in charge of maintenance and power plant. High-caliber man capable of handling men. Application by letter. Location, Middle West. V–2717.

YOUNG MEN, high grade, to travel through the great manufacturing and industrial districts to install, inspect, and test electrical instrument and temperature controlling equipment; special consideration will be given to applicants who have had experience in handling instruments, meters, gauges, recorders, controllers, etc.; educated men preferred; unusual chance for promotion. Application by letter, stating experience, education, age, and salary desired. Headquarters, New York City V–2721.

DRAFTSMAN, college graduate preferred, experienced in hoisting and conveying machinery. Application in person. Location, New York City. V–2722.

PATENT ATTORNEY (Young Man). Duties to follow up cases in office, the preparation and presentation of cases handled by an outside attorney. Application by letter. Location, New York City. V–2723.

ENGINEER-DRAFTSMAN capable of plotting surveys, etc., from field notes and doing miscellaneous engineering work under direction. Desire single man and expect employees to remain in Venezuela for period of 18 months, at end of which time, they are entitled to 50 days' leave, expenses coming to this country and returning to Venezuela being borne by company. Application by letter. Location, Venezuela. Headquarters, Philadelphia, Pa. V–2725.

ASSISTANT TO DRYER ENGINEER. Must have construction experience, drafting, and dryer. Application by letter. Location, New York City. V–2728.

ENGINEER to design reinforced concrete and structural steel. Familiar with building laws of New York and Philadelphia. Application in person. Location, Philadelphia, Pa. V–2732.

ARCHITECTURAL DRAFTSMAN, experienced designer. Work on institutional buildings. Application in person. Location, Philadelphia, Pa. V–2733.

EXECUTIVE SECRETARY by large Engineering Society in the East. Technically trained man at least thirty-five with experience in secretarial management, practical handling of Club, technical publication, and general Club House management. Tact, initiative, and ability to meet men of affairs essential. Application by letter, stating experience in detail and accustomed compensation. V–2737.

ASSISTANT RESIDENT ENGINEER for water-supply work, which includes all phases from earth excavation to installation of machinery. Should have building construction experience. Must be willing to live at job. Application in person. Location, New Jersey. V–2742.

DRAFTSMEN who have had intimate contact with sugar industry, and are really good draftsmen on power plant and general industrial work, including transmission, conveyors, tanks, and other miscellaneous apparatus. Preference shown to those who have had sugar experience, although other competent men will be considered if necessary. Position will be open in near future. Application by letter only. Location, New York City. V–2750.

ENGINEER thoroughly qualified for responsible position in connection with plant and machinery layouts, installation of machinery, design of supporting structures, design of both the above and machine design, preparation of cost estimates, and engineering office routine. Prefer man with civil, mechanical, and some chemical engineering experience. References. Application by letter, stating salary expected and availability. Location, New York State. V–2751.

DISTRICT MANAGER for high temperature heating material. Applicant must be familiar with Pittsburgh, Pa., and surrounding section. Application by letter. Headquarters, New York City. V–2757.

SALES ENGINEER for sub-agencies in the following district: Southern Ohio, Kentucky, and Western West Virginia. Company manufactures road machinery, contractors' equipment, etc. All engineering supervision in drawings, specifications, and publicity furnished. Application by letter. Headquarters, Ohio. V–2761.

CIVIL, ELECTRICAL, OR MECHANICAL ENGINEER for writing up specifications on automatic machine switching. Application in person. Man about 25 to 30. Location, Ill. V–2777.

IRRIGATION ENGINEER as Assistant for determination of seepage losses in irrigation canals. Should be capable of observing and noting conditions influencing the tests; should be in good health, willing to work, and should have had experience in measuring the discharge of canals and small streams. Application by letter. Location, Texas. V–2792.

PROFESSOR for head of Department of Civil Engineering. Do not apply unless willing to accept when definite offer is made. Application by letter. Location, Porto Rico. V–2795.

SALES ENGINEER to sell Industrial Conveyors. Must have well balanced combination of engineering, analytical, and selling ability. Will be called on to facilitate, expedite, and economize movement and transportation of materials through and out of processes of production in all kinds of Industrial Plants and handle all sorts of things by means of conveyors in many different mercantile and commercial establishments. Must be able to analyze processes and economical factors involved thoroughly and have sufficient ability to instil confidence, inspire respect, and carry conviction. Application by letter. Location, New York State. V–2802.

SALESMEN well versed in elevating and conveying work, who might be put directly on sales work, with only a short apprenticeship on estimating, simply to give a little familiarity with our products and methods. Application by letter. Headquarters, New York State. V–2807.

SALESMAN for outside work. Columbia man preferred. Sales experience with construction and industrial plants. Application in person. Location, New York City. V–2813.

SALESMAN AND SALES MANAGER. Company makes "Quick Fire" which is a preparation to be added to motor gasoline to prevent formation of carbon. Work is selling to garage keepers and repair shops. Application in person. Location, New York and East. V–2819.

SUPERVISOR of installation of heating, ventilating, and power plant equipment. Should be thoroughly experienced in this work. Application by letter. Location, New York City. V–2820.

ENGINEER for sales office work for routine matters. Sales experience with construction and industrial plants. Application in person. Salary not stated. Location, New York City. V–2822.

SALESMAN for soliciting contracts. Man will be assisted by General Electric man in soliciting lighting jobs. Young man preferred. Application by letter. Location, New York City. V–2823.

SYRACUSE AND ALBANY, N. Y., DISTRICT REPRESENTATIVES of fast growing company, specializing in complete accountancy service for medium and small businesses. Requirements—successful sales experience among business executives; general knowledge and appreciation of accountancy principles. Technical education preferred. Remuneration, straight commission paid monthly on total business in force. Income small at first, but builds up rapidly. Application by letter, giving complete history. Headquarters, New York State. V–2826.

BUILDING SUPERINTENDENT to act as architect's representative on work. Application by letter. Salary not stated. Location, New York City. V–2871.

STRUCTURAL STEEL DESIGNER with power plant building experience. Application in person. Salary $200 to start. Location, New York City. V–2881.

GENERAL MANAGER for New York Eng. Co. having in hand and nearly all financed, railroad and other development in two foreign stable countries, possessing valuable exclusive rights and grants in connection therewith and needing temporary capital to keep going until put over. No limit to age either way if can supply the few thousands needed for next few months to hold engineers and promoters. If active interest in enterprises is desired, can have anything wanted and organize to suit, in co-operation with present staff. Further particulars and complete information to right party. Application by letter. V–2884.

ARCHITECT'S SUPERINTENDENT familiar with Hotel, Residential and Office Building work. Must be familiar with ornamental plastering, plumbing, etc. Age 35 to 45 years. Application by letter. Location, New York City. V–2889.

FIELD ENGINEER capable of taking charge of transmission line survey party. Experienced man only. Application in person. Salary not stated. Location not stated. V–2903.

REINFORCED CONCRETE DESIGNERS (3) experienced on foundation work and power plants. Experienced men only. Application in person. Salary not stated. Location not stated. V–2904.

HYDRAULIC ENGINEER for field and office investigation work. Experienced man only. Application in person. Salary not stated. Location, New York City. V–2905.

MEN AVAILABLE

YOUNG CIVIL ENGINEER; degree C. E. Experience in surveying, industrial buildings, apartments, alterations, concrete and steel, residences, and conveyor design. Available immediately. Location, New York City and Brooklyn, N. Y. CE–368.

DESIGNING ENGINEER, Assoc. M. Am. Soc. C. E.; age 32; Graduate Civil Engineer. Desires position with consulting engineer, engineering firm, or as contractor's engineer. Ten and one-half years' experience, covering design and construction of highway bridges and structures, buildings,

water-works, railways, and port works on private, city, State, Federal, and foreign work. Available, February 15th, 1923. Location in Western States preferred. CE–369.

CIVIL ENGINEER is open for responsible executive position; College graduate. Twenty years' practical experience in design and construction work of all kinds; thoroughly conversant with appraisal work, the preparation of reports and financial statements, and the analysis of general business conditions, in regard to engineering projects. Highest technical and business references. CE–370.

CIVIL ENGINEER, Assoc. M. Am. Soc. C. E.; age 40; married; technical. Seventeen years' experience on miscellaneous engineering and construction work, including designs, heavy earthwork, railroad yards and buildings, etc. Extensive experience in steam and electric railway valuation and maintenance. Now employed in executive position with large utility property. Desires change. Will consider position with railway, industry, or contractor. Personal interview solicited. CE–371.

CIVIL AND MINING ENGINEER, Assoc. M. Am. Soc. C. E.; Member, A. I. M. and M. E.; age 31; married. Desires position with firm engaged in concrete construction, excavation, shaft-sinking, and tunneling. Eleven years' experience in mining and construction work. CE–372.

Assoc. M. Am. Soc. C. E.; graduate, 1909; age 35; experienced in design of concrete, steel, and other materials, specialized in harbor improvement and concrete bridges, will be free about December 15th, 1922. Will go anywhere. Health good and can stand hot or cold climates equally well. Foreign countries preferred. CE–376.

GRADUATE CIVIL ENGINEER, M. Am. Soc. C. E.; Dr. Eng.; M. Int. Assoc. of Nav. Cong. Specialist in hydrography, river and harbor improvements, port works, and jetty construction. Can design and execute the works indicated. Has had professional experience in the United States, Mexico, Guatemala, Panama, and Brazil. Is familiar with the Portuguese. Spanish and French languages. Best of references furnished. CE–373.

STRUCTURAL ENGINEER. Nineteen years' experience in steel for office and mill buildings, structures for material-handling devices: towers, bridges, derricks, cranes, etc., timber, concrete, and foundations. Mechanical experience in connection with machinery for these devices. Responsible position, plant or office. CE–374.

CIVIL ENGINEER, Yale graduate, M. Am. Soc. C. E. Twenty-five years' experience (20 years in charge of engineer office and in executive positions), on heavy construction work (concrete, stone, earthwork), river and harbor improvements, roads, railroad work, etc. Recently in South America for about two years in responsible charge of work for prominent firm of American contracting engineers, to whom reference will be made. Available at once for position anywhere. Salary $5 000 to $8 000, dependent on location and character of work. CE–375.

NEW BOOKS*

(From October 1st to October 31st, 1922)

The statements made in these notices are taken from the books themselves, and this Society is not responsible for them.

DONATIONS TO ENGINEERING SOCIETIES LIBRARY

ADVANCED LABORATORY PRACTICE IN ELECTRICITY AND MAGNETISM.

By Earle Melvin Terry. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. 261 pp., illus., diagrams, 9 x 6 in., cloth. $3.00.

This book is intended for those students who have only one year for the study of electricity and magnetism, in addition to the work covered in an elementary course in general physics. In addition to the usual work in electrical measurements, the book includes a study of the discharge of electricity through gases, radio-activity, and thermionics. The book covers the work given to third-year students of electrical engineering at the University of Wisconsin.

JIGS, TOOLS, AND FIXTURES: THEIR DRAWING AND DESIGN.

By Philip Gates. N. Y., D. Van Nostrand Co., 1922. 195 pp., illus., diagrams, tab., 7 x 5 in., cloth. $2.50.

This simple book on the drawing and design of jigs, tools, and fixtures, covers equipment for practically all modern machine tools. Chapters are devoted to drill jigs, milling fixtures, chucks, cutters, taps and dies, gauges, press tools, etc. A chapter on office procedure is also given. The subject is presented in a simple, practical manner.

CONDENSED CATALOGUES OF MECHANICAL EQUIPMENT, 12th ANNUAL, 1922.

N. Y. American Society of Mechanical Engineers, 1922. 622 pp., illus., 12 x 9 in., fabrikoid. $5.00.

The twelfth issue of this convenient reference book appears in new form; the book now having a 7 by 10-in. type page and being printed on thin India paper and bound in flexible covers. In other ways, the volume follows the plan of previous years. It contains catalogue information, condensed, uniformly presented, and illustrated, about the products of 372 manufacturers of mechanical equipment; a classified directory of manufacturers of equipment, in which 4 200 firms are listed under 3 300 headings; and a directory of consulting engineers, containing the names and addresses of 1 000 engineers, under 400 headings. In each of these divisions, the new issue shows enlargement and thorough revision.

AIRCRAFT YEAR BOOK, 1922.

N. Y., Aeronautical Chamber of Commerce of America, 1922. 251 pp., illus., diagrams, tab., 9 x 6 in., cloth. $3.20.

A general review of the year's progress in aviation prepared especially for those interested in its commercial development. The book also contains a discussion of the problems of aerial transportation, an account of the comparative effectiveness of aerial and naval armament, a review of aeronautics in different countries, and an account of technical progress in construction during the year. The second section contains a collection of aircraft and engine designs, chiefly recent. The Appendix contains information on the aircraft trade associations, the Government bureaus dealing with aviation, and various commercial and historical tables.

AUTOMOTIVE REPAIR; VOL. 2, FOR ELECTRICAL SERVICE MEN.

By J. C. Wright. N. Y., John Wiley & Sons; Lond., Chapman & Hall, 1922. 417 pp., illus., diagrams, 9 x 6 in., cloth. $3.00.

The second volume of this comprehensive manual for repairmen treats of the electrical equipment of automobiles. It presents carefully detailed instructions for fifty-six electrical repair jobs, covering the derangements that occur most frequently. These are fully illustrated with drawings and photographs. In addition, an account of electrical theory is given, sufficient for a thorough understanding of the functions of the electrical equipment of automotive vehicles.

CHILTON TRACTOR INDEX, JULY, 1922.

Phila., Chilton Company, 1922. 336 pp., illus., 10 x 7 in., paper, $2.00.

* Unless otherwise specified, these books have been donated by the publishers.

Directories of manufacturers of tractors, of farm power-machinery, threshers, plows, cultivators, electric plants, etc., and of tractor parts and equipment are given as well as specifications and prices of the various machines on the market. There are also indexes of trade names. The Index is a convenient summary of technical and trade information frequently needed by makers and users of tractors and farm machinery.

HAND BOOK OF CASINGHEAD GAS.

By Henry P. Westcott. Third Edition. Erie, Pa., Metric Metal Works, 1922. 642 pp., illus., tab. 8 x 5 in., cloth. $3.75.

The author of this work has endeavored to collect, in one volume of convenient size, all the chemical, physical, and engineering information on the extraction of gasoline from natural gas, which is likely to be needed by the man in the field. It treats of the examination and leasing of gas wells, determination of their capacity, and the gasoline content of the gas, gathering lines, measuring gas, compression, absorption, blending, transportation, etc. Although few radical changes in methods have been developed since the preceding edition of the book was published, many minor improvements have been made, which are now described.

BROWN'S DIRECTORY OF AMERICAN GAS COMPANIES AND GAS ENGINEERING

And Appliance Catalogue, 1922. N. Y., Robbins Publishing Co., 1922. 966 pp., illus., 12 x 9 in., cloth. $10.00.

The book is divided into two sections. The first section is a catalogue of gas-plant equipment, which contains an alphabetical index of the firms represented, a classified index to their products, and condensed catalogues describing them. A catalogue of books on the gas industry is included. The second section is a directory of gas companies. It contains an index of the cities and towns supplied with gas, statistics of the gas companies of North America, and of holding and operating companies, financial reports of holding and operating companies, the high and low prices of gas securities, a list of public service commissions, and an alphabetical list of the members of the leading gas associations.

WELDING ENCYCLOPEDIA.

By L. B. Mackenzie and H. S. Card. Second Edition. Chic., Welding Engineer Publishing Co., 1922. 388 pp., illus., tab., charts, 9 x 6 in., fabrikoid. $5.00.

This work is intended as a reference book on the theory, practice, and application of the four processes for autogenous welding. The first half of the book is a dictionary of the words, terms, and trade names used in the industry. Included in this are instructions for the common types of repair and production work, descriptions of tests, specifications for rods and wires, and descriptions of the application of welding in various industries. Following the dictionary are separate chapters on the four processes for welding, giving detailed descriptions of each and instructions for its use. Chapters on boiler, tank, pipe, and rail-joint welding are then given, followed by a section on the regulations of Federal and State authorities, and insurance companies, and a chapter on the heat treatment of steel. A collection of charts and tables and a catalogue section are also provided.

ESSAIS DE SOUDURES AUTOGÈNE ET ÉLECTRIQUE DE PIÈCES DE CHAUDIÈRES.

By E. Hoehn. Paris, Ch. Béranger, 1922. 78 pp., illus., diagrams, 9 x 6 in., paper. 4 francs.

This report gives the results of an extensive series of tests of autogenous and electric welds as applied to boiler construction, carried out in 1921 by the Association Suisse de Propriétaires de Chaudières à Vapeur. The points investigated included the welding of flanges to tubes and boiler shells, the welding of plates at right angles, tensile tests of different forms of welds, the influence of skin on welds, the quasi-arc electric process, and the strength of welded tanks.

UNTERSUCHUNGEN UND NEUERUNGEN AN VENTILKOMPRESSOREN.

Von J. C. Breinl. München, R. Oldenbourg, 1922. 110 pp., diagrams, illus., 10 x 7 in., paper. 252 marks.

This book contains a record of the results obtained in an extended study of air-compressor valves, and is of interest to designers and manufacturers.

UNTERSUCHUNGEN AN DAMPFSTRAHLAPPARATEN.

Von F. Heinl. (Forschungsarbeiten auf dem Gebiete des Ingenieurwesens. Heft 256.) Berlin, Julius Springer, 1922. 23 pp., 10 x 7 in., paper. 20 marks.

The author gives the results of an investigation to determine whether the circulation in hot-water heating systems can be maintained by means of one or more injectors fed with high-pressure steam, instead of by the usual methods. The specific points examined were the heat given to the water by the injected steam, under the most favorable conditions, at any given rate of injection and pressure, and the possibility of regulating the apparatus by varying the quantity of water. The tests were made on a model system built for the purpose. A study of the action of injectors is included.

DIE STATIK DES KRANBAUES.

Von W. Ludwig Andrée. Dritte Auflage. München, R. Oldenbourg, 1922. 370 pp., diagrams, 10 x 7 in., paper. 348 marks.

The author gives eighty examples of static calculations for cranes and similar structures. These examples include traveling, cantilever, bridge, rotary, gantry, portal, floating, tower and shipbuilding cranes, aerial ferries, cableways, hoist frames, inclined bridges, grab buckets, and swing and bascule bridges. This edition is apparently a reprint of the second.

FOUNDRYMEN'S HANDBOOK.

Based on Data Sheets from *The Foundry*. Cleveland, Ohio, Penton Publishing Co., 1922. 309 pp., tab., 9 x 6 in., cloth. $5.00.

Since 1907, *The Foundry* has regularly published "data sheets", containing practical information on matters of interest to foundrymen. The result is a large accumulation of general and scientific data, specifications, formulas, and recipes, which are now presented in classified form, with an index, in a convenient volume for reference use.

BLAST FURNACE AND THE MANUFACTURE OF PIG IRON.

By Robert Forsythe. Third Edition, Revised by C. A. Meissner and J. A. Mohr. N. Y., U. P. C. Book Co., 1922. 371 pp., illus., diagrams, tab., 9 x 6 in., cloth. $4.00.

Most recent writers on this subject have, in Mr. Forsythe's opinion, addressed themselves too exclusively to those acquainted with it. He, therefore, has written this concise statement of general principles, treated on essentially American lines, for beginners. The present edition has been revised by two expert blast-furnace managers, in order that it may present the practice of to-day.

METALLURGICAL AND ANALYTICAL APPLICATIONS OF THE SPECTROGRAPH.

Lond., Adam Hilger, Ltd., 1922. 12 pp., 9 x 6 in., paper.

This brochure contains three fine photogravures showing the arc spectra of pure lead, pure copper, and lead and copper in combination. The accompanying text discusses the application of the spectrograph in metallurgy and chemical analysis. A bibliography on quantitative spectrum analysis is included.

OIL ENCYCLOPEDIA.

By Marcel Mitzakis. N. Y., John Wiley & Sons; Lond., Chapman & Hall, 1922. 551 pp. 9 x 5 in., cloth. $6.00.

This encyclopedia covers a wide range of information interesting to those engaged in the oil industry. Brief articles are devoted to engineering and geological subjects, localities where oil occurs, commercial information, and the history of the industry. A brief bibliography is included. The work will be interesting to those engaged in the oil trade.

HANDBOOK OF THE PETROLEUM INDUSTRY.

By David T. Day. N. Y., John Wiley & Sons; Lond., Chapman & Hall, 1922. 2 v., illus., diagrams, tab., 9 x 6 in., fabrikoid. $15.00.

The scope and authoritativeness of this work are shown by the contents and contributors. It is written with especial reference to the engineers who produce and refine oil, but is also addressed to the public interested in the increase of production and the better utilization of the oil supply. Throughout the book, attention has been directed to present conditions, and historical matter has been omitted. Contents: The Occurrence of Petroleum, by Frederick G. Clapp; Field Methods in Petroleum Geology, by Frederic H. Lahee; Oil-Field Development and Petroleum Production, by Louis C. Sands; Statistics of Petroleum and Natural Gas Production, by Annie B. Coons; Transportation of Petroleum Products, by Forrest M. Towl; Characteristics of Petroleum, by David T. Day; Petroleum Testing Methods, by T. G. Delbridge; Natural-Gas Gasoline, by H. C. Cooper; Asphalt, by R. G. Smith; Oil Shale, by David E. Day; Refining, by A. D. Smith; Cracking Processes, by Roland B. Day; Use of Fuel Oils, by W. N. Best; Internal Combustion Petroleum Engines, by Arthur H. Goldingham; Lubrication, by John D. Gill; Pipe Standards and Use of Pipe, by F. N. Speller; General Tables; Current Petroleum Literature; Glossary; Index.

STUDY OF GEOLOGICAL MAPS.

By Gertrude L. Elles. (Cambridge Geological Series.) Cambridge, Eng., University Press, 1921. 74 pp., pl., diagrams, maps, 10 x 7 in., cloth. $4.00. (Gift of Macmillan & Co.)

This book is intended to direct the attention of students to the fundamental principles of geological map-reading, and to show what can be obtained from maps when read intelligently.

MANUAL OF SEISMOLOGY.

By Charles Davison. (Cambridge Geological Series.) Cambridge Univ. Press, 1921. 256 pp., illus., diagrams, 9 x 6 in., cloth. $7.00. (Gift of Macmillan & Co., N. Y.)

The author has given an outline of present knowledge of the origin of earthquakes, their distribution, nature, intensity, frequency, propagation, and effects. As the volume belongs to a series of geological manuals, special attention is given to the geological aspects of the subject, rather than to those of a mathematical or physical character. Good bibliographical footnotes are included.

DUST EXPLOSIVES.

By David J. Price and Harold H. Brown. Bost., National Fire Protection Association, [1922]. 246 pp., illus., diagrams, tab., 9 x 6 in., cloth. $3.00.

The authors of this book are engineers and chemists connected with the Bureau of Chemistry of the U. S. Department of Agriculture, who have been engaged in an investigation of dust explosions in mines and factories. In the present work, they consider the nature and theory of dust explosions, what explosions have done, and what has been learned by studying those that have occurred in various industries. They then discuss the measures that have proved most effective in preventing explosions or retarding their development when started. A bibliography is included.

EXAMINATION OF HYDRO-CARBON OILS AND OF SAPONIFIABLE FATS AND WAXES.

By D. Holde. Second English Edition Translated from the Fifth German Edition by Edward Mueller. N. Y., John Wiley & Sons; Lond., Chapman & Hall, 1922. 572 pp., illus., tab., 9 x 6 in., cloth. $6.00.

This manual offers the oil chemist, in one compact volume, general methods for investigating oils, petroleum and petroleum products, lubricants, natural asphalt, ozocerite, tars from various bituminous materials, saponifiable fats, and industrial products prepared from them, and waxes. This edition has been practically rewritten. Many completely new sections on special oils have been introduced, practically all chapters have been fundamentally revised, and much information included on the substitutes for oils and fats used by the German oil industry during the World War.

CALCULATIONS OF QUANTITATIVE CHEMICAL ANALYSIS.

By L. F. Hamilton and S. G. Simpson. N. Y. and Lond., McGraw-Hill Book Co., 1922. 200 pp., 8 x 5 in., cloth. $2.00.

This is a text on the calculations of quantitative analysis that (1) permits the instructor to devote more time in the classroom to the chemistry of quantitative analysis; (2) aids the student in grasping stoichiometric principles without extensive personal instruction; (3) provides ample material for home assignments and for quizzes; and (4) prepares the way to more difficult problem work in physical and engineering chemistry.

VAN NOSTRAND'S CHEMICAL ANNUAL.

Edited by John C. Olsen. Fifth Issue, 1922. N. Y., D. Van Nostrand, 1922. 900 pp., port., charts, tab., 7 x 5 in., fabrikoid. $4.00.

This book is intended to supply, in convenient form, the tables and numerical data most frequently required by chemists. The present fifth edition has been carefully revised and enlarged. The literature has been searched for new data on the compounds listed in the book and corrections have been made when necessary. A considerable number of new compounds have been included, and about forty-six new tables have been added.

INTRODUCTION TO THE CHEMISTRY OF RADIO-ACTIVE SUBSTANCES.

By A. S. Russell. Toronto, Macmillan Company of Canada, 1922. 173 pp., tab., charts, 8 x 5 in., boards. $2.00. (Gift of Macmillan Co., N. Y.)

The author has given a short account of the chief facts concerning the chemistry of radio-active substances at present known, which is intended for students of the subject. It is stated to be, as far as the author is aware, the only book in English, which is reasonably up-to-date.

ORIGIN OF SPECTRA.

By Paul D. Foote and F. L. Mohler. (American Chemical Society, Monograph Series.) N. Y., Chemical Catalog Co., Inc., 1922. 250 pp., plates, diagrams, tab., 9 x 6 in., cloth. $4.50.

Although several accounts of the mathematical aspects of the quantum theory of spectra have appeared recently, the authors of this book feel that too little attention has been paid to the experimental consideration of the problem. The present book, therefore, is devoted to the presentation of the experimental results that have been achieved and their relation to theoretical developments. The volume forms one of the series of monographs issued by the American Chemical Society.

PATENT ESSENTIALS.

By John F. Robb. N. Y. & Lond., Funk & Wagnalls Co., 1922. 436 pp., pl., charts, 9 x 6 in., cloth. $5.00.

This text treats of the nature of patents, the mechanism of their procurement, claim drafting, conduct of patent cases, and special proceedings, including forms. It is the work of an experienced patent attorney, but is intended for laymen who wish to understand the essentials of law and practice before the Patent Office, rather than for experts.

EXPORT MERCHANDISING.

By Walter F. Wyman. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. 405 pp., illus., 9 x 6 in., cloth. $4.00.

The book contains an extended discussion of the principles on which the American exporter should base his efforts, with advice concerning proper practical methods. All phases of exporting are discussed by an experienced exporter.

SCIENCE OF PURCHASING.

By Helen Hysell. N. Y., D. Appleton Co., 1922. 261 pp., 8 x 5 in., cloth. $2.50.

The author discusses the qualifications of a purchasing agent, the principles and policies to be adopted, the legal, economic, and ethical principles to be observed, and the organization and conducting of purchasing departments.

THOMAS' REGISTER OF AMERICAN MANUFACTURES, 1922.

N. Y., Thomas Publishing Co., 1922. 4 500 pp., 9 x 12 in., cloth. $15.00.

The Register answer immediately the three usual questions that arise in every purchasing department. It contains lists of the makers of more than 70 000 articles and gives the capital rating and address of each. It also furnishes a directory of manufacturers, giving their addresses, lines, branches, etc. Section 3 lists more than 50 000 trade named articles, with the names of their manufacturers. For many years a standard directory, this edition has been carefully revised to the time of issue.

COST CONTROL AND ACCOUNTING FOR TEXTILE MILLS.

By Eugene Szepesi. N. Y., Bragdon, Lord & Nagle Co., 1922. 441 pp., tab., 9 x 6 in., fabrikoid. $10.00.

As suggested by the Contents, this book discusses the various factors that contribute to the cost of manufacturing textiles and the methods of determining their several contributions. A system of cost accounting is described in detail, which is adapted to the needs of manufacturers of textiles. Contents: Cost Control Factors of an Article; Cost of an Article; Labor; Burden of the Product; Burden and Its Proper Application; General Burden and Its Factors; Determining the Burden at the End of the Month; Manufacturing Waste, Its Control and Relation of Cost; Control Accounts of a Modern Cost Control Organization; Records of Control in General; Control Records of Material Requirements; Control Records of Supplies and Supply Purchases; Raw Materials, Their Physical Control and Control Records; Control Records of Goods in Process; Construction of Production Records; Production Orders and Other Records Authorizing Production; Records of Registering Progress of Production; Cost Without Red Tape.

DAVISON'S TEXTILE "BLUE BOOK".

Thirty-fifth Annual Edition, July, 1922, to July, 1923. N. Y., Davison Publishing Co., 1 670 pp., 9 x 7 in., cloth. $7.50.

The text covers all phases of the textile industry, including manufacturers, dealers, and commission merchants, in every kind of textiles, as well as dealers in textile supplies. The directory entries give concisely the location, officers, number of employees, and products of each mill, arranged geographically. The edition has been thoroughly revised.

HIGHWAYS GREEN BOOK.

Third Annual Edition. Wash., D. C., American Automobile Assoc. 1922. 427 pp., illus., port., 9 x 6 in., cloth. $3.00.

The book contains a convenient summary of the important highway activities of 1921. The information includes accounts of road improvements under Federal, State, and local control, a number of papers on construction and maintenance, and articles on other engineering and economic topics. Will be useful to all students of current highway development.

INVENTION OF THE TRACK CIRCUIT.

N. Y., Signal Section, Am. Ry. Assoc., 1922. 113 pp., illus., port., 10 x 7 in., paper.

In honor of the Fiftieth Anniversary of the invention of the track circuit by Dr. William Robinson of Brooklyn, N. Y., the present volume has been prepared by a Special Committee of the Signal Section of the American Railway Association. Section 1 gives a history of the invention, Robinson's patent, and his own description of the invention. Section 2 is a memorial to W. A. Baldwin, formerly General Superintendent of the Pennsylvania Railroad, who first installed automatic block signals controlled by track circuits. Section 3 describes the track circuit as used to-day. Section 4 treats of European usage.

LUMBER, ITS MANUFACTURE AND DISTRIBUTION.

By Ralph Clement Bryant. N. Y., John Wiley & Sons; Lond., Chapman & Hall, 1922. 539 pp., illus., map, tab., 9 x 6 in., cloth. $4.50.

This book is intended as a text and reference book for students in lumbering. It treats first of the manufacturing plant, discussing its location and arrangement, log storage, saw-mill equipment, saws, handling and transfer equipment, and power plants. The second section is devoted to lumber manufacture, and deals with labor, sawing, and trimming, seasoning, re-manufacture of lumber, lumber products, mill refuse, and fire prevention. The concluding section, on markets and marketing, treats of lumber trade associations, grades and inspection, transportation, domestic and foreign markets, import trade, and tariffs. The Appendix contains a bibliography, a glossary, and tables of statistics. The text covers a subject on which few general books are available.

WOOD-PRESERVING TERMS.

By Ernest F. Hartman and E. F. Paddock. N. Y., Protexol Corporation, 1922. 85 pp., 9 x 6 in., paper. $1.00.

The book is a useful glossary of terms used by wood preservers, including chemical, pathological, and engineering terms, as well as those which are merely industrial. The definitions frequently are encyclopedic in fullness and accompanied by references to the literature, so that the pamphlet forms a convenient reference work.

CEMENTS, LIMES, AND PLASTERS.

By Edwin C. Eckel. Second Edition. N. Y., John Wiley & Sons, Lond., Chapman & Hall, 1922. 655 pp., illus., diagrams, maps, tab., 9 x 6 in., cloth. $6.50.

This book is a summary covering the composition and character of the raw materials used for cementing structural materials, the methods of manufacturing the latter, and their properties. The author pays especial attention to the chemical and physical processes underlying the manufacturing methods, but also discusses costs, output, etc. The new edition has been extensively revised and 100 pages have been added, chiefly relating to Portland and magnesian cements and gypsum products.

REINFORCED CONCRETE SIMPLY EXPLAINED.

By Oscar Faber. (Oxford Technical Publications.) Lond., Henry Frowde and Hodder & Stoughton, 1922. 77 pp., diagrams, 9 x 6 in., cloth. $1.70. (Gift of Oxford Univ. Press, American Branch.)

This book is intended for readers who do not aspire to a specialist's knowledge, but want a clear understanding of the general principles involved in reinforced concrete, so as to be able to make simple designs safe, but not necessarily the last word in economy, and to take an intelligent interest in reinforced concrete construction.

STRUCTURAL PROBLEMS.

By C. R. Young. Second Edition. Toronto, Eng. Soc., Univ. of Toronto, 1922. 96 pp., diagrams, 9 x 6 in., paper. $2.00.

These are typical problems in the design of steel and timber structures, prepared to assist students in elementary structural design and used in the author's classes at the University of Toronto as guides in the preparation of similar designs. The problems do not constitute a systematic development of the subject, but indicate the method of applying structural theory to the design of a number of simple structures and members. Intended to supplement lectures and textbooks.

HYDRAULIC PRINCIPLES GOVERNING RIVER AND HARBOR CONSTRUCTION.

By Curtis McD. Townsend. (Engineering Science Series.) N. Y., Macmillan, 1922. 189 pp., tab., 9 x 6 in., cloth. $2.60.

During his professional career, Col. Townsend has prepared numerous projects and has answered many criticisms of the methods used in the improvement of rivers and harbors, and this book is derived principally from these sources. It treats of the formation of rivers, the flow of water in rivers, the flow of sediment, flood prediction, river regulation, dikes, canalization, dredging, removal of obstructions, reservoirs and levees, flood-protection, estuaries, river mouths, harbors, and the economics of water transportation. A bibliography is included. The work is an excellent statement of the principles governing the flow of water in natural channels.

CURRENT CIVIL ENGINEERING LITERATURE

KEY TO ABBREVIATED REFERENCES TO PUBLICATIONS INDEXED*

Abbreviated References.	Publication.	Place.
Am. C. Inst	*American Concrete Institute, Proceedings* (Y.)	Detroit
A. I. E. E.	*American Institute of Electrical Engineers. Journal* (M.)	New York
A. R. E. A.	*American Railway Engineering Association, Proceedings* (Y.)	Chicago
A. S. T. M.	*American Society for Testing Materials, Proceedings* (Y.)	Philadelphia
Am. Soc. C. E.	*American Society of Civil Engineers, Proceedings* (M.)	New York
Am. Soc. Mun. Impvts.	*American Society for Municipal Improvements, Proceedings* (Y.)	New York
Am. W. W. Assoc.	*American Waterworks Association, Journal* (Bi-M.)	Baltimore
Am. Wood Prs. Assoc.	*American Wood Preservers Association. Proceedings* (Y.)	Baltimore
Ann. P. et C.	*Annales des Ponts et Chaussées* (Bi-M.)	Paris
Ann. T. P. Belg.	*Annales des Travaux Publics de Belgique* (Bi-M.)	Brussels
Assoc. Ing. Gand	*Annales de l'Association des Ingénieurs sortis des Ecoles Spéciales de Gand* (Q.)	Ghent
Bost. Soc. C. E.	*Boston Society of Civil Engineers, Journal* (M.)	Boston
Can. Engr	*Canadian Engineer* (W.)	Toronto
Cem. Eng	*Cement and Engineering News* (M.)	Chicago
Cornell C. E.	*Cornell Civil Engineer* (M.)	Ithaca
Dock & Harbour	*Dock and Harbour Authority* (M.)	London
Eisenbau	*Der Eisenbau* (M.)	Leipsig
Eng.	*Engineering* (W.)	London
Eng. & Contr.	*Engineering and Contracting* (W.)	Chicago
Eng. Inst. Can.	*Engineering Institute of Canada, Journal* (M.)	Montreal
Eng. N. R.	*Engineering News-Record* (W.)	New York
Engrs. Club, St. L.	*Engineers Club, St. Louis, Journal* (Bi-M.)	St. Louis
Engrs. Soc. Pa.	*Engineers' Society of Pennsylvania, Journal* (M.)	Harrisburg
Engrs. Soc. W. Pa.	*Engineers' Society of Western Pennsylvania, Journal* (M.)	Pittsburgh
Engr.	*Engineer* (W.)	London
Engrs. & Eng.	*Engineers and Engineering, Engineers' Club of Philadelphia* (M.)	Philadelphia
Gen. Civ.	*Le Génie Civil* (W.)	Paris
Gesund. Ing.	*Gesundheits Ingenieur* (W.)	Munich
Inst. C. E.	*Institution of Civil Engineers Minutes of Proceedings* (Q.)	London
Inst. Mun. & Co. Engrs.	*Institution of Municipal and County Engineers, Journal* (W.)	London
Int. Ry. Assoc.	*International Railway Association, Bulletin* (M.)	Brussels
Land. Arch.	*Landscape Architecture* (M.)	Harrisburg
Mech. Eng.	*Mechanical Engineering* (M.) *Journal of the American Society of Mechanical Engineers*	New York
Mil. Engr.	*Military Engineer* (M.)	Washington
Min. & Metal.	*Mining and Metallurgy* (M.) *American Institute of Mining Engineers*	New York
Mun. & Co. Eng.	*Municipal and County Engineering* (M.)	Indianapolis
N. E. W. W. Assoc.	*New England Water Works Association, Journal* (M.)	Boston
N. Y. R. R. Club	*New York Railroad Club, Proceedings* (M.)	Brooklyn
Oest. Ing. Arch. Ver.	*Oesterreichischer Ingenieur und Architekten Verein, Zeitschrift* (W.)	Vienna
Power	*Power* (W.)	New York
Rev. Gen.	*Revue Générale des Chemins de Fer* (M.)	Paris
Ry. Age	*Railway Age* (W.)	New York
Ry. Main. Engr.	*Railway Maintenance Engineer* (M.)	Chicago
Ry. Rev.	*Railway Review* (W.)	Chicago
Schw. Bauz.	*Schweizerische Bauzeitung* (W.)	Zurich
Sci. Am.	*Scientific American* (M.)	New York
Soc. Ing. Civ. Fr.	*Société des Ingénieurs Civils de France, Mémoires et Comptes Rendus* (Q.)	Paris
Ver. deu. Ing.	*Verein deutscher Ingenieure, Zeitschrift* (W.)	Berlin
West. Ry. Club	*Western Railway Club, Proceedings* (M.)	Chicago
West. Soc. Engrs.	*Western Society of Engineers, Journal* (M.)	Chicago
Zeit. Bau.	*Zeitschrift fur Bauwesen* (Q.)	Berlin
Z. d. Bauver.	*Zentralblatt der Bauverwaltung* (Semi-Weekly)	Berlin

* Y = Yearly; Q = Quarterly; M = Monthly; F = Fortnightly; W = Weekly.

A. Applied Sciences

a. Processes of Calculation

2. Graphical and Nomographical Processes

Einheitliche Bezeichnungen für die Festigkeitsberechnungen von Ingenieurbauwerken.* (Uniform Symbols for Calculations of the Strength of Engineering Structures.) Schaper. Z. d. Bauver. Sept., '22.

B. Applied Mechanics

a. Mechanics of Solids (Strength of Materials)

2. Elastic Solids

Bending Moments in Pins or Shafts Determined Graphically.* A. M. Winslow. Eng. N. R. Oct. 5, '22.

Verdrehung von Vierkanteisen mit Quadratischem und rechtechkigem Querschnitt.* (Torsion of Quadrangular Iron with square and rectangular Section.) Dassen. Eisenbau. Aug., '22.

Verdrehversuche mit Stäben von kreuzförmigem Querschnitt.* (Torsion Tests with Bars of Cross-shaped Section.) A. Föppl. Ver. deu. Ing. Sept. 2, '22.

Biegung durchlaufender Platten und rechteckiger Platten mit freien Rändern.* (Flexure of Continuous Plates Rectangular Plates with Free Edges.) A. Nadai. Ver. deu. Ing. Sept. 9, '22.

3. Jointed Systems

Beitrag zur Theorie der veränderlich gegliederten und gestützten Systeme.* (Contribution to the Theory of Variable Articulated and Supported Systems.) M. Geller. Eisenbau. Serial beginning Aug., '22.

6. Heterogeneous Solids (Reinforced Materials)

Torsional Strength of Reinforced Concrete Beams.* C. R. Young. Can. Engr. Oct. 10, '22.

Calcul et Répartition des Etriers d'une Pièce Fléchie en Béton Armé. (Calculation and Distribution of Supports for a Bent Piece of Reinforced Concrete.) A. Taton. Gen. Civ. Sept. 2, '22.

7. Pulverulent Masses (Earth Pressure)

The Distribution of Pressure on Surfaces Supporting a Mass of Granular Material.* Frank Harvey Hummel and E. J. Finnan. Inst. C. E. 1920–21, Pt. 2.

Les Procédés Géophysiques d'Etude du Sous-Sol.* (Geophysical Processes for the Study of the Subsoil.) J. Michaut. Gen. Civ. Serial beginning Sept. 2, '22.

b. Hydraulics

1. Processes of Measurement

An Investigation of the Herschel Type of Weir.* Richard H. Morris and Albert J. R. Houston. Mech. Eng. Oct., '22.

3. Industrial Hydraulics

The Amritsar Hydro-Electric Irrigation Installation.* Stephen Leggett. Inst. C. E. 1920–21, Pt. 2.

Hydraulic Turbines.* Lewis F. Moody. (Paper read before Univ. of Toronto.) Can. Engr. June 20, '22.

Queenston-Chippawa Hydro Power Development.* Can. Engr. July 4, '22.

Nipigon Hydro-Electric Power Development.* Can. Engr. Aug. 1, '22.

Water Power Situation in the St. Lawrence Region.* J. T. Johnston. Can. Engr. Sept. 19, '22.

Ueber Schwerkraftspannungen in Rohrleitungen von grossen Durchmessern und deren rationelle Konstruktion.* (Upon Stresses due to Gravity in Large Diameter Pipe Lines and the Rational Construction of the same.) Karl I. Karlsson. Schw. Bauz. Sept. 2, '22.

Pneumatic Mail Tubes and Operation of Automatic Railroads.* Kenneth E. Stuart. Engrs. & Eng. Oct., '22.

The Hydraulic Turbine in Evolution.* H. Birchard Taylor and Lewis F. Moody. Mech. Eng. Oct., '22.

First Pit River Power Project is Completed.* Eng. N. R. Oct. 5, '22.

Elektrizitätswerk "Zeleni Vir".* (The "Zelenie Vir" Electricity Works.) Z. d. Bauver. July 21, '22.

Die Wasserkraftanlage an den Norefällen in Norwegen.* (The Water Power Plant at the Nore Falls in Norway.) Eger. Z. d. Bauver. Sept. 9, '22.

C. Materials of Construction and General Processes

a. Lime, Cement, Mortar, Concrete, Brick, Bitumen, Timber, Gravel, etc.

The Effect of Sugar on Cement and Concrete.* William Norman Thomas. Inst. C. E. 1920–21, Pt. 2.

Promoting the Art of Making Good Concrete.* D. A. Tomlinson. Ry. Main. Engr. Serial beginning Oct., '22.

Nouveaux Procédés de Mélange de Matériaux et des Liants dans la Fabrication du Béton et des Pierres Artificielles. (New Processes for Mixing the Materials and Binders in the Manufacture of Concrete and Artificial Stone.) R. Marc. Gen. Civ. Sept. 28, '22.

Würfelfestigkeit und Feuchtigkeitsgrad des Betons.* (Cubic Strength and Degree of Dampness of Concrete.) W. Petry. Z. d. Bauver. Sept. 2, '22.

b. Metals

Standardisation des Câbles Métalliques. Association Belge de Standardization. (Standardization of Wire Rope.) Assoc. Ing. Gan. Pt. 3, '22.

Versuche mit Weicheisen.* (Researches on Soft Iron.) Richard Baumann. Ver. deu. Ing. Sept. 2, '22.

Messing als Werkstoff für Kondensatorrohre.* (Brass as Material for Condenser Tubes.) A. Schimmel. Ver. deu. Ing. Sept. 9, '22.

f. Rock Excavation. Mining. Rock Removal

Abstracts of Institute Papers to be Presented at the San Francisco Meeting September, 1922.* Min. & Metal Sept., '22.
Nouvel Appareil de Sondage, Système Otlet.* (New Well Drilling Apparatus, Otlet System.) G. Claus. Gen. Civ. Sept. 9, '22.
Abbaueinwirkungen auf Schächte und Massnahmen zu ihrer Verhütung.* (Effects of Mining upon Shafts and Methods for Protecting Them.) Von Marbach. Ver. deu. Ing. Sept. 16, '22.

g. Execution of Works. Specifications

How to Eliminate Waste in Construction Industry. D. Knickerbacker Boyd. (Paper read before Am. Construction Council.) Can. Engr. Sept. 19, '22.
Construction Costs. W. N. Connor. (From paper read before Construction Industries Conference.) Can. Engr. Oct. 17, '22.

3. Of Wood

Greenheart as Teredo Resistant on Panama Locks.* C. J. Embree. Eng. N. R. Oct. 12, '22.
Beispiele neuzeitlicher Holzbauweisen.* (Examples of Modern Methods of Wooden Construction.) Lewe. Z. d. Bauver. Sept. 20, '22.

5. Of Reinforced Concrete

Reinforced Concrete for Water Retaining Structures. H. C. Ritchie. (Paper read before Inst. Water Engrs.) Can. Engr. July 25, '22.
La Construction des Jetées et Appontements en Béton Armé.* The Construction of Piers and Flying Bridges of Reinforced Concrete.) Gen. Civ. Sept. 23, '22.

h. Foundations

Foundation Tests for Nebraska State Capitol.* Eng. N. R. Oct. 12, '22.

j. Piles and Pile-Driving

Destructive Action of Marine Borers. Hermann von Schrenk. (Paper read before Am. Assoc. of Port Authorities.) Can. Engr. Sept. 26, '22.
Bond Strength of Wood Piles in Concrete.* R. R. Lundahl. Am. Soc. C. E. Oct., '22.
Pile Foundations and Clay. H. C. H. Shenton. (From *The Surveyor.*) Can. Engr.. Oct. 10, '22.

k. Tunnels and Tunneling-Shields

Colorado Prepares New Plans for Moffat Tunnel.* Ry. Age Sept. 23, '22.
Der Ausbau des zweiter Simplontunnels.* (The Completion of the Second Simplon Tunnel.) C. Andreae. Z. d. Bauver. Sept. 23, '22.
Der Bau des Simplontunnels II (19.825 m.). (The Construction of the Simplon Tunnel II.) C. J. Wagner. Oest. Ing. Arch. Ver. Sept. 29, '22.

D. Highways

c. Construction

Controlling Quality of Materials in Highway Construction. John H. Bateman. (Paper read before Conference on Highways Eng., Univ. of Mich.) Can. Engr. June 20, '22.
Portland Cement Concrete Roads. James Allen. (Paper read before Canadian Good Roads Assoc.) Can. Engr. June 20, '22.
Drainage Methods for Prairie Roads. H. R. MacKenzie. (Paper read before Canadian Good Roads Assoc.) Can. Engr. June 27, '22.
Improving Earth, Clay and Sand Roads. J. D. Robertson. (Paper read before Canadian Good Roads Assoc.) Can. Engr. June 27, '22.
Inspection and Control of Concrete Materials. R. W. Crum. (Paper read before Iowa Eng. Soc.) Can. Engr. July 25, '22.
Road Drag Competition in Saskatchewan. H. S. Carpenter. (Paper read before Canadian Good Roads Assoc.) Can. Engr. July 25, '22.
Selection of Mineral Aggregates for Concrete Roads. Duff A. Abrams. (Paper read before Am. Road Builders' Assoc.) Can. Engr. Aug. 1, '22.
Design of Rigid Type Road Surfaces.* A. T. Goldbeck. (From paper read before Am. Assoc. of State Highway Officials.) Can. Engr. Aug. 8, '22.
Laying Concrete Culvert Pipe.* Paul Kircher. Ry. Rev. Sept. 23, '22.
Experiment in Asphalt Paving at Philadelphia, Pa. Julius Adler. Eng. N. R. Sept. 28, '22.
Road in Inaccessible Canyon Built by Novel Method.* Eng. N. R. Sept. 28, '22.
Methods That Get Results in Bitumin Road Crossings.* John Stanley Crandell. Ry. Main. Engr. Oct., '22.
Value of Present Tests for Granite in Determining Probable Wear in Pavements. Clarence D. Pollock. Mun. & Co. Eng. Oct., '22.
Constructing Bituminous Concrete Pavement on Crushed Stone Base on Heavy Traffic Providence-Danielson Pike in Rhode Island.* Irving W. Patterson. Mun. & Co. Eng. Oct., '22.
Effect of Initial Pavement Design Upon Costs.* Walter E. Rosengarten. Can. Engr. Oct. 3, '22.
Methods of Constructing Brick Pavements. Arthur H. Blanchard. (Paper read before Conference on Highway Eng. Univ. of Michigan.) Eng. & Contr. Oct. 4, '22.
A Systematic Survey of Gravel for Roads. Wallace Purrington. (Paper read before Am. Road Builders' Assoc.) Eng. & Contr. Oct. 4, '22.
Paving the Streets of Zion with Concrete.* Eng. & Contr. Oct. 4, '22.
Practice in Tar Road Construction in Great Britain. Eng. N. R. Oct. 5, '22.
Concrete Road Tests Completed at Pittsburg, Cal. Eng. N. R. Oct. 5, '22.
Construction and Maintenance of Low Cost Road Surfaces. William N. Bosler. (Paper read before Highway Convention, Univ. of Kentucky.) Can. Engr. Oct. 17, '22.

Pavement "Explosions" Continue for Five Years.* Eng. N. R. Oct. 19, '22.
Ein Kapitel aus dem Wege- und Strassenbau.* (A Chapter on Road and Street Building.) O. Giger. Schw. Bauz. Sept. 16, '22.

d. Maintenance

Experiments in Improving and Maintaining Our Prairie Roads. K. A. Clark. Can. Engr. June 27, '22.
Road Oils and Their Properties as Demonstrated by Current Tests.* C. M. Baskin. Can. Engr. Aug. 8, '22.
How an Illinois County Maintains Its Highways. C. L. Melcher. (Paper read before Convention of Illinois County Superintendents of Highways.) Eng. & Contr. Oct. 4, '22.

e. Street Cleaning, Dust Prevention, Snow Removal

Street Cleaning Methods and Costs at Akron, Ohio.* Frank C. Tolles. Eng. N. R. Sept. 28, '22.

g. Machinery and Tools

Economical Methods of Handling Materials. H. L. Bowlby. (Paper read before Canadian Good Roads Assoc.) Can. Engr. June 27, '22.

h. Vehicles. Automobiles. Traffic

Efficient Methods of Providing for Traffic During Highway Construction. A. R. Hirst. (From paper read before Conference on Highway Eng., Univ. of Michigan.) Can. Engr. July 4, '22.
Maximum Weights, Speeds, etc. of Motor Trucks. C. W. Cornell. (Paper read before Canadian Good Roads Assoc.) Can. Engr. July 11, '22.
Modern Transport. Hugh McDiarmid. Inst. Mun. & Co. Engrs. Sept. 26, '22.
Effect of Wheel Diameter on Highway.* J. R. Kemp and D. A. Crawford. (From *The Commonwealth Engineer*.) Eng. & Contr. Oct. 4, '22.
Government Road Tests Show Progress.* Eng. & Contr. Oct. 4, '22.
How Pennsylvania Marks Its Detours. Eng. & Contr. Oct. 4, '22.
Traffic Capacity and Width of Highways. H. C. Smith. (From paper read before National Highway Traffic Assoc.) Eng. & Contr. Oct. 4, '22.
Marking System for Illinois State Roads.* Ralph R. Benedict. Eng. N. R. Oct. 12, '22.

x. Miscellaneous

Organization and Personnel as Applied to Roads in Scotland. A. Forbes and James Andrew. Inst. Mun. & Co. Engrs. Sept. 26, '22.
Quarry and Road Plant.* William Ellacott. Inst. Mun. & Co. Engrs. Sept. 26, '22.
The Road Problem in South Africa. D. E. Lloyd Davies. Inst. Mun. & Co. Engrs. Oct. 10, '22.
Colorimetric Test for Concrete Sand Studied.* Charles E. Proudley. Eng. N. R. Oct. 12, '22.

E. Bridges, Viaducts, and Arches

b. Iron or Steel Bridges and Viaducts

Plans of Types of Metallic Superstructure for Rail-Bridges.* Albert Ronsse. Int. Ry. Assoc. July, '22.
Revised Steel Railway Bridge Specification, Canadian Engineering Standards Association. Can. Engr. July 11, '22.
Surfacing Driveway of Victoria Bridge.* Irving H. Parker. Can. Engr. July 11, '22.
Annapolis River Bridge, Annapolis Royal, N. S.* E. M. Archibald. Can. Engr. July 25, '22.
The Strength of Railway Bridges. J. S. Wilson. (Paper read before British Assoc.) Eng. Sept. 15, '22.
Double Deck Highway Bridge at East Angus, Que.* Edward Holgate. Can. Engr. Sept. 26,' 22.
Tentative Specifications for Steel Railway Bridges.* Discussion: Charles Evan Fowler and Alfred S. Niles. Am. Soc. C. E. Oct., '22.
Strengthening Truss Bridge Over Tracks at Chicago.* Eng. N. R. Oct. 12, '22.
Strassenbrückenbauten in Altserbien und Mazedonien.* (Highway Bridge Construction in Old Servia and Macedonia.) Oest. Ing. Arch. Ver. July 21, '22.
Die Verstärkung der Eisenbahnbrücken, eine notwendige Voraussetzung für die Einführung von Grossguterwagen und von schwereren Lokomotiven.* (The Strengthening of Railroad Bridges, a Necessary Premise for the Introduction of Large Freight Cars and of Heavy Locomotives.) Kommerell. Ver. deu. Ing. Sept. 23, '22.

d. Concrete and Reinforced Concrete Bridges and Viaducts

Note sur le Pont-Route de Randan (Ligne de Riom à Vichy).* (Note on the Rondan Highway Bridge (Line from Riom to Vichy.) E. Chartiée et G. Blot. Rev. Gen. Sept., '22.
Pont en Béton Armé, a Castelnaudary (Ande).* (Reinforced Concrete Bridge at Castelnaudary (Ande). Paul Thomann. Gen. Civ. Sept. 2, '22.
A Modern Specification for Concrete Bridge Construction. Can. Engr. July 11, '22.
Cumming's Bridge Across Rideau River, Ottawa.* Guy R. Dale. Can. Engr. Aug. 1, '22.
Placing Concrete by Several Methods on Same Job.* Eng. N. R. Sept. 28, '22.
The Comparison of Concrete Groined Arches as an Aid in Their Design.* Philip O. Macqueen. Am. Soc. C. E. Oct., '22.
Building a Five-Span Concrete Bridge in Cold Weather.* G. F. Scales. Eng. N. R. Oct. 5, '22.
Boldly Designed Center for Heavy Concrete Arch.* Eng. N. R. Oct. 19, '22.

h. Computations, Tests, etc.

Locomotive Loadings for Railway Bridges.* Discussion: C. D. Purdon, Robert C. Strachan, Victor H. Cochrane, Albert Lucius, B. A. Worthington, G. H. Gilbert, J. A. L. Waddell,

Gustav Lindenthal, R. A. Caughey, J. C. Ralston, J. C. Biand, J. M. Johnson, C. S. G. Rogers, E. A. Stone, Harold C. Bird, Almon H. Fuller, Carlton T. Bishop, Clyde W. MacCornack, and C. P. Disney. Am. Soc. C. E. Oct., '22.

F. Inland Waters

b. Canals (General Articles)

Capacity of Panama Canal Ample for at Least 30 Years.* J. K. Baxter. Eng. N. R. Oct. 19, '22.

c. Regulation of Waterways—Volume of Discharge, Freshets, Floods, Soundings

Silt.* Herbert Chatley. Inst. C. E. 1920–21, Pt. 2.
Silt Observations of the River Tigris.* Alfred Dale Lewis. Inst. C. E. 1920–21, Pt. 2.
The Measurement of the Discharge of the Nile Through the Sluices of the Assuan Dam.* Murdoch MacDonald and H. E. Hurst. Inst. C. E. 1920–21, Pt. 2.
Flood Discharge and the Dimensions of Spillways in India.* George Branby Williams. Engr. Sept. 29, '22.
Island Removal Causes Scour Upstream.* Ivan E. Houk. Eng. & Contr. Oct. 11, '22.
Studies of Flow Through Cleared and Uncleared Floodways.* Charles E. Ramser. Eng. N. R. Oct. 12, '22.
Flow in Tennessee Checked Against Hydraulic Formulas.* Benjamin E. Jones. Eng. N. R. Oct. 12, '22.

d. Diverting Dams. Locks. Lifts. Elevators. Inclined Planes

Some Notes on the Location and Construction of Locks and Movable Dams on the Ohio River, with Particular Reference to Ohio River Dam No. 18. Discussion: Gardner S. Williams and Morris Knowles. Am. Soc. C. E. Oct., '22.
Schleusen und bewegliche Wehre im kanalisierten Ohio.* (Sluices and Movable Weirs on the Canalized Ohio.) Schinkel. Z. d. Bauver. Sept. 13, '22.
Wehranlage in der Weser bei Bremen.* (Weir Installation on the Weser at Bremen.) I. Kölle. Schw. Bauz. Sept. 23, '22.

j. River and Lake Ports, Equipment

Illiana Harbor. W. V. Judson. West. Soc. Engrs. July, '22.
Petroleum Spirit Dock on the Manchester Ship Canal.* Engr. Sept. 29, '22.

k. Utilization of Inland Waterways, Freight, Capacity

Water Borne Transportation Inland and Marine.* John Millis. West. Soc. Engrs. Oct., '22.

G. Maritime Works

g. Dredges and Dredging. Force Pumps. Refloating and Removing Wrecks. Ice-Breakers

The Grab Dredger.* W. A. Oglethorpe. Dock and Harbour Oct., '22.
Suggestions for the Installation and Operation of Dredging Pumps.* Cem. Eng. Oct., '22.

h. Wharves. Mooring Buoys. Harbor Equipment

Factors at a Port Which Determine the Kind and Amount of Freight Handling Machinery. B. F. Cresson, Jr. (From paper read before Am. Assoc. Port Authorities.) Can. Engr. Oct. 3, '22.
Le Port de Pêche de Lorient (France).* (The Lorient (France) Fishing Port.) D. Bouckaert et J. Mullie. Ann. T. P. Belg. Aug., '22.

i. Harbors (General Articles)

Port Improvements at Newcastle, New South Wales.* Percy Allan Inst. C. E. 1920–21, Pt. 2.
Cork Harbour Development.* George F. Nicholson. Dock and Harbour Serial beginning Oct., '22.
Control of Waste Fuel Oil in Harbors. Bancroft Hill. (From paper read before Am. Assoc. of Port Authorities.) Can. Engr. Oct. 3, '22.
Seaports in Nation and World Planning. Cyrus Kehr. (Abstract of paper before Am. Assoc. of Port Auth.) Can. Engr. Oct. 17, '22.
Richtlinien für die Aufstellung von Hafenbebauungsplänen.* (Guides for the Arrangement of Harbor Construction Plans.) Fabricius. Z. d. Bauver. Sept. 16, '22.

k. Utilization of Inland Waterways. Freight. Capacity

Tidal Berths and River Jetties.* Du-Plat-Taylor. Dock and Harbour Serial beginning Oct., '22.

H. Railroads. Street and Interurban Railways. Automobiles. Aeronautics

a. Railroads

1. General articles

Development of Concrete in Railway Construction.* M. Hirschthal. Ry. Age Oct 14, '22.
Das Gedingeverfahren in den Werkstätten der Deutscher Reichsbahn.* (The Contract Method in the Workshops of the German State Railroad.) Hans A. Martens. Ver. deu. Ing. Sept. 23, '22.
Compte Rendu Sommaire des Séances de la 9e Session du Congrès International des Chemins de Fer Tenue à Rome en 1922. (Summary Report of the Meetings of the 9th Session of the International Railway Congress, held at Rome in 1922). Rev. Gen. Sept., '22.

2. Location
Reverse Studies Detect Errors in Railroad Location. C. K. Conard. Eng. N. R. Sept. 28, '22.
3. Roadbed. Construction Work. Tunnels
Laying Concrete Culvert Pipe.* Paul Kircher. Ry. Rev. Sept. 23, '22.
4. Track
Cleaning Track with a Power Driven Sweeper.* Ry. Age Oct. 7, '22.
Tie Preservation on Danish Railroads.* Eng. & Contr. Oct. 18, '22.
Oberbau für erhöhte Raddrücke.* (Permanent Way for Increased Wheel Loads.) Stierl. Ver. deu. Ing. Sept. 23, '22.
Eiserne Hohlschwelle.* (Hollow Iron Ties.) Ver. deu. Ing. Sept. 23, '22.
5. Signals and Safety Apparatus
Train Orders by Signal Indications.* A. R. Fugina. Ry. Age Sept. 23, '22.
6. Rolling Stock (Locomotives, Cars)
St. Paul Adopts Water Treatment on Large Scale.* C. Herschel Koyl. Ry. Age Sept. 23, '22.
The Ljungstrom Turbine-Driven Locomotive.* Ry. Age Sept. 23, '22.
Design and Operation of the Unit Railway Steam Car.* Ry. Rev. Sept. 30, '22.
Recording Riding Qualities of Cars.* F. Crocker. Ry. Rev. Sept. 30, '22.
Extensive Boiler-Water Treating on C., M. & St. P. Ry.* C. Herschel Koyl. Eng. N. R. Oct. 5, '22.
Steam Desaturators Applied to Hungarian Motive Power.* Desider Ledacs Kiss. Ry. Rev. Oct. 7, '22.
The Design of Modern Steel Freight Car Equipment.* John A. Pilcher. (Paper read before Ry. Club of Pittsburg.) Ry. Rev. Oct. 7, '22.
The Performance of Locomotive 7 000 on the Union Pacific.* Ry. Rev. Oct. 14, '22.
Service Records of U. P. Mountain Type Locomotives.* Ry. Age Oct. 14, '22.
Modifications Apportées par la Compagnie de l'Est a son Système de Chauffage des Trains.* (Modifications added by the Eastern Company to Its System for Heating Trains.) Rev. Gen. Sept., '22.
Les Nouvelles Voitures-Lits de la Compagnie Internationale des Wagons-Lits.* (The New Sleeping Cars of the International Sleeping Car Company). Gen. Civ. Sept. 16, '22.
Die Kunze-Knorr-Güterzugbremse.* (The Kunze-Knorr Freight Car Brake.) Kurt Wiedemann. Ver. deu. Ing. Sept. 23, '22.
Grossgüterwagen für Massenverkehr.* (Large Freight Cars for Bulk Transportation.) Gustav Laubenheimer. Ver. deu. Ing. Sept. 23, '22.
Die Grundlagen des Arbeitsdiagrammes eines Lokomotiv-untersuchungswerkes.* (The Basis of the Working Plan of a Locomotive Testing Works.) Neesen. Ver. deu. Ing. Sept. 23, '22.
Mechanische Lokomotivfeuerungen.* (Mechanical Locomotive Firing.) F. Meineke. Ver. deu. Ing. Sept. 23, '22.
7. Use of Electricity
The Electrification of the Turin-Cirie-Valleys of Lanzo Railway with Continuous Current at 4 000 Volts.* A. S. (From *Revista dei Trasporti.*) Int. Ry. Assoc. Sept., '22.
I. C. Adapts Electrification to Terminal Traffic.* Ry. Age Oct. 21, '22.
L'Electrification du Chemin de Fer de Turin à Ceres en Courant Continu à 4 000 Volts. (Electrification of the Railroad from Turin to Ceres with 4 000-Volt Continuous Current.) Gen. Civ. Sept. 16, '22.
Die Hochspannungsleitung Bevers-Albulawerk der Rhätischen Werke für Elektrizität.* (The Bevers-Albula-Plant High-Tension Line of the Rætian Electric Works.) G. Lorenz. Schw. Bauz. Serial beginning Sept. 16, '22.
8. Stations. Engine Houses. Shops
New Shop Agreements Have Novel Features. Ry. Age Sept. 10, '22.
New Engine House Construction on the Southern Pacific.* Ry. Rev. Sept. 23, '22.
Work Under Way on Union Station Headhouse.* Ry. Age Sept. 30, '22.
A Temporary Passenger Station of Unusual Design.* Ry. Main. Engr. Oct., '22.
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PAPERS AND DISCUSSIONS

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AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE WATER POWER PROBLEM*

A SYMPOSIUM

PAGE

With Discussion by Messrs. J. M. Howells and M. M. O'Shaughnessy.

* Presented at the Fall Meeting of the Society, at San Francisco, Calif., on October 4th and 5th, 1922, and continued from November, 1922, *Proceedings*.

AERIAL PHOTOGRAPHY AS AN AID IN MAP MAKING, WITH SPECIAL REFERENCE TO WATER POWER SURVEYS

By Gerard H. Matthes,* M. Am. Soc. C. E.

The purpose of this paper is to bring to the attention of the Profession a method of utilizing aerial photographs in the preparation of maps, which has been used with considerable success in a recent survey of the Tennessee River. The method appears to be well adapted for use in water power surveys, irrigation surveys, city planning, and the location of highways. It utilizes to the fullest possible extent the information furnished by the photographs, and eliminates the necessity of providing triangulation or other costly forms of ground control. In this respect, it departs not only from ordinary survey methods, but also from most of the systems of aerial mapping evolved to the present time.

As a result of the experimental work with aerial photography, that has been done in the United States and abroad, two distinct products have been developed: The mosaic, made by joining a number of photographs into what purports to be a continuous photographic reproduction of a part of the earth's surface; and the hand-drawn map compiled from aerial photographs, which has the appearance of an ordinary map. This paper is devoted mainly to a consideration of the hand-drawn map, including both the plane and the topographic map. A brief description of the mosaic has been added for the purpose of making clear its advantages and limitations. No practical method has yet been evolved for showing the relief by means of contours by direct photographic or stereoscopic process. Some progress in that respect has been made in France and Germany, but in this country it is still necessary to supplement the contours by surveying. This is best accomplished by the plane-table method, either by drawing the contours on skeleton maps prepared from the photographs, or, by drawing the contours directly on the photographs. The success that the speaker has had with the latter method inclines him to the belief that eventually it may find wide application.

The Mosaic

The mosaic gained its popularity during the World War when quick work in locating enemy positions, rather than the production of maps, was essential. The usual method of constructing a mosaic is by fitting and pasting to a suitable backing, parts of adjoining photographs. This is done by selecting the clearest and best parts of the photograph, usually their centers, and discarding the remainder in such a manner as to leave a feathered edge of irregular contour. This feathered edge avoids the appearance of distinct matching lines in the finished product, and, when wetted, it may be stretched and squeezed a certain amount, which is a great aid in securing perfect matching of contiguous details.

In a sense, each component photograph of a mosaic is a miniature map, that is, assuming it to have been taken with the focal plane of the camera held truly parallel to the ground surface. Unfortunately, with the best equip-

* U. S. Asst. Engr., Chattanooga, Tenn.

ment, it is impossible to take all the photographs in one flight, not to mention several adjacent flights, at the same altitude, or with the focal plane of the camera always parallel to the ground surface at the time of exposure. Nor is the surface of the ground a plane surface. From these sources of error result the following: (*a*) differences in the scale of the photographs due to the varying altitude of the airplane; (*b*) distortions due to tilting of the camera at the instant of exposure; and (*c*) displacements of objects from their true positions, due to inequalities in the elevations of the land.

However slight these errors may be, and they usually are slight, their sum total makes the construction of a first-class mosaic quite difficult, and if great care is not exercised, only indifferent results can be expected. Unless some form of control is available, that will serve as a check on the position of objects at frequent intervals, there is no assurance that the scale of the mosaic can be made dependable. In the case of mosaics of cities, such a check is usually obtainable by comparison with existing maps, but where no accurate map is available, a ground control, by triangulation or other survey methods, must be established and this greatly increases the cost. Even with the best of control, it is at times difficult to avoid unsightly offsets in mosaics, due to distorted parts not matching properly.

The inaccuracies that are inherent in ordinary mosaics do not operate to debar them from many practical uses. Thus, they are excellent as reconnaissance maps, and for other purposes that do not require the accurate scaling of distances or the close measuring of areas. Mosaics possess the merit of being obtained usually at a small outlay of cost and time. Until greatly improved methods are evolved for taking photographs from the air, the field of usefulness of the mosaic, to the engineer, is likely to remain limited.

Hand-Drawn Maps

Under this subject will be considered maps that are compiled by transferring information from aerial photographs directly to tracing linen, or to paper. The special method advocated herein is not applicable to the mapping of large areas on relatively small scales, such as the standard base map of the U. S. Geological Survey, etc., for the reason that the primary requirements of maps of that class are to show the objects in their correct positions with respect to meridians and parallels or grid lines, and to take due account of the sphericity of the earth. It is obvious that the requirements of such maps cannot be attained through the use of photographs, except by providing a rigid system of triangulation, that will effectually place each particle of information derived from the photographs in its proper geographic position.

The new method appears to be especially suited to the class of maps required by the practising engineer in the planning of engineering works. However heterogeneous in aspect and purpose, the maps required for engineering purposes may be, they differ as a class from geodetically accurate maps in three important particulars: (*a*) they are not units in a comprehensive mapping scheme; (*b*) the location of objects with respect to meridians and parallels is not essential; and, (*c*) the limit of permissible error is fixed by considerations of a practical rather than of a cartographic nature. There is an unlimited

field for the application of aerial photography in the preparation of engineers' maps, but it has not received the attention that has been accorded it in the production of geodetically accurate maps.

The experience gained on the survey of the Tennessee River demonstrates that, within certain limits, excellent results can be obtained without resorting to any form of horizontal control other than that derived from the photographs themselves.

It is not the province of this paper to give a detailed description of the process of constructing aerial photographic maps used by the Army Air Service, as descriptions thereof are available.* An outline of the process is here given in order to enable the reader to judge in what respect it differs from the method about to be described.

The method used by the Air Service consists in covering the region systematically with overlapping courses of photographs and in determining the correct position of the individual photographs, on tracing cloth or celluloid, by the Bagley method of orientation a description of which is given subsequently. Adjustment is then made so as to bring the position of the photographs in accord with the horizontal control. After this is accomplished, a skeleton map is compiled on sheets suitable for use on a plane-table by transferring the major details from the photographs by the use of a pantograph. These sheets are then ready for the topographer to take into the field. All this pre-supposes, however, that the necessary spirit-level and triangulation control has been provided.

The Survey of the Tennessee River†

The primary objects of this survey and investigation were to ascertain the possibilities of constructing dams across the Tennessee River and its principal tributaries for the joint development of water power and navigation. Secondary objects were the securing of data for use in studies of flood control and the development of the mineral resources of the region, in so far as these subjects had a bearing on power and navigation. It was recognized from the beginning that an accurate and detailed map would be needed, that should furnish all necessary information for making preliminary estimates of cost of structures and land damages; also, that such a map should be of sufficient scope to show the territory adjacent to the river for a distance of a mile or more, in order that intelligent study might be given to the location of industrial sites with reference to flood levels, water and rail transportation, power-transmission lines, highways, and towns. Existing maps did not furnish this information, nor was it possible by combining all available sources of information to compile a dependable map fulfilling these requirements. This deficiency arose from the fact that the quadrangle maps of the U. S. Geological Survey of this region were inadequate, being on a scale of 1:125 000, the surveys having been made nearly 40 years ago, whereas the river charts prepared by the U. S.

* "The Use of Aerial Photographs in Topographic Mapping," *Information Circular No. 184*, published by the Chief of Engineers, U. S. Army, 1921.

† Ordered by the River and Harbor Act of June 5th, 1920.

Engineer Department, although drawn to a large scale, supplied no information outside the river banks.

The new map was undertaken on a field scale of 1:15 000 (about 4 in. equal 1 mile) and a scale of publication of 1:20 000. It was to show all water-courses, the configuration of river banks, islands, and sloughs of large streams; all railroads, highways and roads, including private roads in the vicinity of the river; all isolated buildings of importance; all the more important property lines as indicated by fences, and the classification of lands as follows: (*a*) high priced, cultivated lands; (*b*) hilly farm lands; and (*c*) wooded, rocky, or gullied lands. The relief was also to be shown by 5-ft. contours in the valley bottoms and 10 ft. contours on the hillsides, thus making it possible to compute the areas of lands that would be overflowed for any reasonable height of dam that might be planned in any given locality. The contours were located for a distance of at least 60 ft. above extreme low water in the Tennessee River.

The main object in using aerial photography was to expedite this undertaking and thereby to save cost. It was estimated that about 2 000 sq. miles in the form of a narrow ribbon covering many hundreds of miles of river valley would have to be mapped, and the funds available were inadequate for securing, by ordinary survey methods, a topographic map of the desired scope and accuracy.

There was little precedent that would serve as a guide. A number of topographic maps, however, had been made with the aid of aerial photographs, and a limited supply of literature was available on that general subject, but hardly any of it seemed to fit the particular case in hand.

The co-operation of the Army Air Service was enlisted for taking the photographs, and this resulted in the photographing of the valley from Knoxville to Chattanooga, Tenn., during the summer of 1921. In October of that year, at the inception of mapping operations, a method was tried out involving the sketching of contours directly on aerial photographs, and this gave promise of good results from the beginning. It consisted of taking stadia topography by the plane-table method, and platting the points, as fast as they were located, on the photographs. The contours were then sketched, the photographs sent to the office, and the information on them transferred to tracing cloth into final map form.

Although contour sketching on photographs had been done to a considerable extent in France and Germany, and experimentally in the United States by the U. S. Army and the U. S. Geological Survey, no instance is known of such work having been done methodically over any large area in this country, previous to its adoption in the survey of the Tennessee River. The field work on this survey was conducted for eight consecutive months, when the funds became exhausted. During that time, the survey developed from an experiment into a well grounded system of map making, the results of which surpass the older methods of surveying and mapping in the degree of faithfulness and completeness of detail obtained and by the saving in time and cost. The following is a description of the various phases of the work.

Aerial Operations.—The photographing was done by two officers of the Army Air Service from a De Haviland plane equipped with a camera of the K-1 type, which had a single lens of 10-in. focal length. It was necessary to fly the plane at an altitude of 12 500 ft., in order to obtain photographs on a scale of 1:15 000. The photographs measured about 7 by $8\frac{3}{4}$ in. In terms of distances on the ground, these dimensions corresponded to 1.66 by 2.07 miles.

The photographic equipment, although not of the latest type, was complete, and included the following accessories: An adjustable gimbal-like support for the camera, which permitted it to be leveled quickly, and to be rotated; a Venturi vacuum tube which served to hold the film flat against the focal plane plate at the instant of exposure; an electric battery for operating the automatic mechanism; a speed-control device for regulating the interval between successive exposures; a view finder which enabled the photographer to determine the proper setting of the speed-control device and the amount the camera must be rotated to compensate for "crabbing" of the airplane due to its position at an angle with the true direction of flight.

The normal velocity of the plane while the photographs were being taken was 85 miles per hour. As the photographs measured 1.66 miles in the direction of flight, and an overlap of 50% was desired, it was necessary to make exposures about $\frac{5}{6}$ mile apart, or at intervals of 35 sec. in still air. In case of wind, proper allowance had to be made, in order to maintain the required lap.

The films came in rolls and were 24 cm. wide by about 75 ft. long, and contained about 100 exposures. As it was not practicable, with the equipment then used, to change films while flying, the work had to be planned to conserve film and time to the best advantage. This was important, as in Tennessee the number of days when atmospheric conditions are favorable for aerial photographic work do not usually average more than 8 per month.

For each day's work, which usually consisted of 2 to 3 hours of flying, the pilot was furnished with a section of map from a quadrangle map of the U. S. Geological Survey, on which were shown, by colored lines, the flights to be made. The work was laid out in parallel and overlapping courses, averaging about 10 to 15 miles in length. Sixty-eight courses were covered, and more than 1 000 photographs were taken of the valley from the head of the Tennessee, near Knoxville, to Chattanooga. The total area covered by photographs was 675 sq. miles, including 188 lin. miles of the Tennessee River, and 20 miles of the Hiwassee River, from the mouth of the latter to Charleston, Tenn. Along the main river, the belt of photographs varied in width from 3 to 9 miles, with an average of 5 miles. The greater widths were made necessary by river meanders and because of having to include certain tributary valleys.

The entire area was covered from one landing field in East Chattanooga. It was common for the aviators to fly to Knoxville, a straight-line distance of about 100 miles, make from 50 to 75 exposures, and, without alighting, return to Chattanooga in time for luncheon.

Because of weather conditions, seven weeks were required in which to complete the aerial work, photographs having been taken on only eleven days of

that period. These figures show that, in the southeastern part of the United States, the cost of aerial photographic work is a function of climate rather than of the size of area covered. Had this photographic work been done in the arid regions of the West, two weeks probably would have been required.

It was intended to have the photographs within any course overlap 40 to 50% in the direction of flight and about 15% between adjacent courses. In some instances, the lap obtained was much less, as may be seen by reference to Fig. 15 which shows a part of the index map prepared for the survey. This index map shows the relative positions of the individual photographs, for general reference, without any attempt at precision. Fig. 15 is not to be taken as representative of the aerial work done on the Tennessee River, but it was selected because of its shortcomings which make it more instructive than a more perfect example.

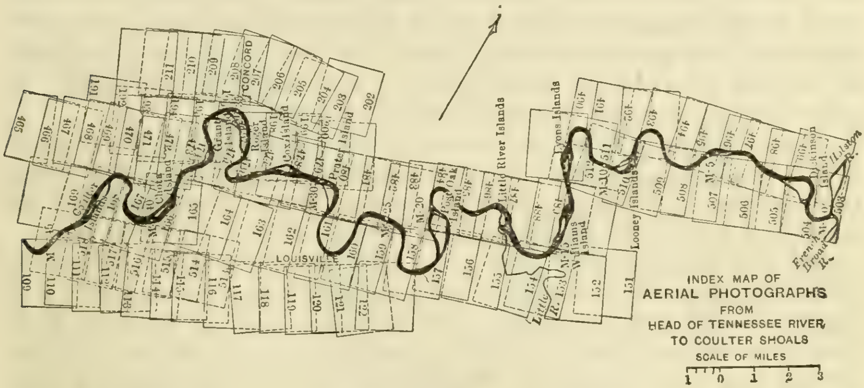

Fig. 15.

Thus, the two long courses, numbered from 151 to 169 and from 465 to 489, show a scant overlap which was the cause of much extra labor in assembling the final map. Again, the short course, numbered 202 to 211, gives evidence of the airplane having had trouble, because of some local atmospheric condition, and, as a result, there is insufficient lap on the course to the south, and at one place there is no lap whatever. In some instances, it was necessary to fly supplementary courses in order to close hiatuses, as, for instance, near Mile 45 on the Tennessee River, where the course numbered 513 to 518 was needed to cover the gap left between the courses numbered 109 to 122 and 151 to 169. As the developing and printing was done at Langley Field, Va., it was sometimes two weeks or more before such troubles became known. The disadvantage of having the dark-room work done at a distance was felt also in other ways, and impressed those in charge with the necessity of the provision, in future work of this kind, for having the developing and printing done locally.

An example of adequate lap is shown by the courses at the extreme right in Fig. 15, both as regards lap within courses as well as between them. Unfortunately, there is hardly any lap between the lower of these two courses

and those immediately to the southwest. This made map construction at that point impracticable by the method adopted. Fortunately, it was possible by reference to the old river survey charts to secure proper continuity of the photographic map. The extent to which these early charts were utilized in checking the aerial photographic map will be discussed in detail subsequently.

The information conveyed by the photographs was largely satisfactory, and more than ample for the purposes of the map. No difficulty was experienced in identifying objects on clear prints, and only a little practice was required in order to interpret the significance of all that showed in the photographs. The most prominent features were the river outlines, the highways being next; railroads were less conspicuous, but were easily recognized by the regularity of their alignment. Cultivated lands, outlines of wooded areas, fence lines, lone trees, and buildings showed plainly. Perhaps the least distinct features were the clay roads and the smaller drainage courses. Among the objects that could not be distinguished and that had to be located by survey were newly built fences and power-transmission lines. The location of power lines could be traced in places by the cleared rights of way through timbered areas. In general, the photographs contained a wealth of detail.

It is to be regretted that the camera was not equipped to record automatically on each photograph the amount and direction of its tilt and the altitude registered by the altimeter. This is now done in the latest equipment and would have been of the greatest value in the orientation work.

The photographic prints used on the Tennessee River survey were of two kinds: A glossy print that showed minute details and was suitable for all purposes except field sketching; and a dull print made on No. 6 P. M. C. bromide paper, which was especially suitable for drawing with ink or pencil, and was used on the plane-table. The bromide prints were not as rich in detail as the glossy prints, and when made from weak negatives gave poor definitions. To overcome their limitations, it became customary to provide the men in the field with glossy prints for reference.

Surveying Operations.—The surveying operations are of particular interest, because of their simplicity as compared with standard methods of surveying, such as would have been used normally to produce a map equal to the one obtained. Thus, in the matter of horizontal control, the aerial photograph supplied all that the surveyor required for locating his instrument station. Triangulation, base lines, control traverses, and the like were unnecessary. The control needed for locating the photographs with respect to each other, under this system, became a drafting-room procedure and will be described subsequently under the head of "The Bagley Method of Orientation."

The vertical control of the Tennessee River work was largely available from previous surveys made by the U. S. Engineer Department, and consisted of permanent bench-marks at intervals of 3 or 4 miles along the river. Check lines were run connecting this old level system (established in 1891) with the precise bench-marks of the U. S. Coast and Geodetic Survey, and except for occasional minor adjustments, it was found to be entirely serviceable. A number of short level circuits were run up tributary valleys, wherever such valleys required mapping for any distance. For the most part, however, height of

instrument elevations for use at the plane-table were carried forward by stadia and vertical angles, always commencing at some permanent bench-mark and closing on such a bench-mark. Such vertical angle traverses seldom exceeded 4 miles in length and usually checked within 0.5 ft.

From the foregoing, it will be seen that, barring a small amount of secondary leveling, the man in the field could devote practically all his time and energy to the contour work. The latter was done with the aid of telescopic alidades mounted on standard plane-tables. The process consisted in determining, by the ordinary stadia and vertical angle method, the location and elevation of important points needed for sketching the contours, and platting these points immediately on the aerial photograph. The photograph was mounted on the plane-table as a sheet of paper on which a map is being platted would have been, with this difference, however, that instead of being a blank sheet it showed the location of objects as seen from the air. This was of great assistance to the topographer, and saved him the trouble of locating such objects. Besides the saving of time effected, it facilitated the work in other ways. First, it enabled the topographer to set his plane-table at practically any desired point by identifying it on the photograph with reference to natural objects. Often a cross-roads, a lone tree, an angle in a fence line, or a bald spot in a field, would serve his purpose. Sometimes an unimportant object like a small bush or a rock, showing plainly in the photograph, served as an instrument station. Where no convenient object could be found, stadia distances taken to near-by objects completed the location quickly. The process of orienting the photograph consisted in sighting the alidade at distant points within the scope of the photograph. The usual three-point problem and many of the vexatious troubles of orientation were avoided.

Perhaps the most important advantage of locating contours on an aerial photograph was the assistance derived from being able to see the objects on the ground portrayed in the photograph. This gave the topographer opportunity to check the location of many of the stadia shots as he platted them. In sketching the contours, he had greater certainty of obtaining the correct alignment of minor bends and angularities in such lines than if he had been sketching on blank paper. The assistance derived from the photographs proved especially helpful in eliminating the tendency of beginners to generalize topographic features by conventionalizing the contours. This fault is easily acquired in field sketching and is usually traceable to inability to see the terrain correctly. The foreshortening of the landscape in the eye of a man standing on the ground is a great obstacle to first-class work, and to overcome it, topographers frequently find it necessary to carry the table to elevated points, in order to do the sketching. Probably the most difficult outlines to reproduce accurately on paper are the shore lines of ponds and rivers, which the eye cannot delineate except from highly elevated points, or by making numerous stadia locations. The aerial photograph eliminates this difficulty, for it shows the shore lines correctly, and it was necessary only to determine a few elevations at controlling points. In a number of cases, comparison of the photographic map with the old river charts showed slight errors in the latter, due to misinterpretation of the curvature of bank lines between stadia loca-

tions. Such errors are practically unavoidable even in the best of surveying practice. The aerial camera supplements this deficiency.

Another advantage of the use of the photograph is that the elevation of any readily identified object can be obtained without the use of the stadia rod, by merely scaling the distance to it on the photograph and reading the vertical angle with the alidade. This, in many respects, is similar to the intersection method of locating points in ordinary plane-table surveying, except that, in this case, the point is already located and only the computation of its elevation is necessary. This method is not recommended for long-range work, as displacements caused by elevation may introduce appreciable errors in the distances scaled.

Fig. 16 conveys some idea of the relative amounts of information obtained from the aerial photographs and through instrumental survey. Fig. 16 is a reproduction of an aerial photograph exactly as it was received from the field party at the Chattanooga Office. The contour lines on the original are drawn in brick red, the small streams in violet, and all cultural details in black. The part supplied by the surveyors, consists of the contour topography and the classification of lands. The latter is indicated by capital letters enclosed in circles and refers to the areas within contours. The notation used is that mentioned on page 1827. The data derived from the photograph consist largely of fence lines, water-courses, roads, buildings, and such other important detail as it seemed desirable to embody in the map. It is to be noted that none of this information required any instrumental work by the surveyors. At the most, an occasional reconnaissance was required by one man, in order to make sure of the location of an important fence line through some woods, or to determine the location of a power-transmission line. As contour points were not determined higher than 60 ft. above low water in the river, the area that had to be covered comprised only 10 to 25% of the finished map. Considering the fact that the control was also derived from the photographs, it will be seen that the field work, although furnishing most valuable data, contributed only a fraction of the information shown; in other words, the photographs alone furnished complete data for a plane map, and all that required surveying were those parts that were of immediate interest in the planning of dams.

Two additional duties imposed on the topographers are not illustrated in Fig. 16. One of these duties was to make determinations of azimuth on Polaris at intervals of about 10 miles, and the other was to test the scale of each photograph by making stadia check measurements between objects 1 500 to 2 000 ft. apart, that could be clearly identified on the photographs and in the field. These check measurements were of great importance, and in the case of any photograph that was not true to scale they had to be repeated in order to test different parts of the photograph. This was necessary not only for the guidance of the topographer in platting stadia distances correctly, but also for making proper allowances in the construction of the skeleton control by the Bagley method of orientation.

Incidental to the survey was the location and determination of the elevation of reliable high-water marks. To facilitate this, the topographers were

FIG. 16.—REPRODUCTION OF AERIAL PHOTOGRAPH AS RECEIVED FROM FIELD PARTY, TENNESSEE RIVER SURVEY.

equipped with river profiles showing the approximate heights attained by certain great floods, compiled from data obtained in previous river surveys. The field organization consisted of one unit, comprising a chief of party, two plane-table topographers, two station assistants, four rodmen, a launch runner, a cook, and a helper. The entire party was housed in a well equipped houseboat which was moved from 5 to 10 miles at a time, the survey progressing in a down-stream direction. A gasoline launch supplemented by a rowboat was used for taking the surveyors back and forth to work and for transporting supplies. The size of the field unit was determined largely by financial considerations. If the survey should be resumed with ample funds, it is planned to increase the field unit so as to comprise three instrument parties and a field draftsman working under the direction of one chief.

Besides doing the administrative work and providing necessary supplies, it was the duty of the chief of parties to plan the work, to determine what part of the area shown on a photograph was to be contoured; and to make reconnaissances for various purposes, including the determination of elevations of distant sink-holes (with aneroid barometer), in order that no area might be overlooked. Finally, it devolved on him to ink the contour lines platted by his topographers and to supply on the photographs other information needed for completing the maps. This included inking in roads, railroads, fence lines, power-transmission lines, buildings, and any other features of importance, as shown in Fig. 16. The putting of the final touches on the photograph in the field was found to be of great utility, for, in this manner, it was possible to go over every contour line in detail, note the discrepancies and omissions, and have the proper corrections made before the photographs were finally transmitted to the Chattanooga Office. With three topographic parties in one unit, it would become necessary to have these duties performed, in part, by a competent draftsman, in order to relieve the chief of parties of too much detail. It may be of interest to state that, in the working plan as first organized, the photographs bearing the contours in pencil were sent to the Chattanooga Office and there inked. The latter plan proved the more satisfactory, for the reasons stated.

The Stereoscope.—Considerable use was made of the stereoscope on the Tennessee River survey, in both the field and the office. The reflecting-mirror type, without lenses, known as the Pellin stereoscope, was found to be best suited for the work, and was used in two forms, the regular, metal-frame, Pellin instrument, and a home-made box-like structure. The latter required artificial illumination and was used with success in the office. Except for the illumination feature, it possessed decided advantages over the regular Pellin type.

The stereoscope brings out the relief of any area common to two overlapping photographs in a most striking manner by exaggerating the vertical scale. This was found to be especially helpful in country of low or moderate relief, for instance, in tracing minor drainage courses the location of which was often indistinct and difficult to follow. It was useful in examining densely forested mountainous areas which, because of the uniformity of the foliage, afforded no clue regarding topography or drainage when

viewed in single photographs. In at least one instance, the presence of deep sink-holes was detected in a hilly and timbered area where the survey party had not suspected the existence of low ground. The discovery was made in the Chattanooga Office; the field party had been instructed to search at points indicated on the photograph, and the low areas were discovered by them and surveyed.

Some of the many practical advantages derived from its use are as follows: In the field, the topographer was enabled, before beginning a day's work, to visualize clearly the character of the topography of the country. Often it showed him the best places to occupy with his instrument. The chief of party, by studying in the stereoscope the country to be mapped, could plan the work more intelligently. In the office, it was possible, by viewing in the stereoscope the photographs on which contour lines had been drawn, to check the accuracy of the sketching. In many other ways, the stereoscope proved so valuable that it soon was considered an essential part of the equipment.

Office Operations.—The office work was wholly unlike that involved in the preparation of any ordinary map. It consisted in taking a set of duplicate photographs and constructing from them the so-called "skeleton control" which, as the words imply, is a skeleton or frame used for assembling the photographs in proper position with respect to each other. The necessity for providing this skeleton control will be apparent when it is remembered that each photograph contained only a small area, averaging perhaps less than 10 sq. in. of data to be traced. It would have been impracticable to trace a succession of such patches by merely fitting or piecing them together without, in so doing, accumulating serious discrepancies in the resulting map. After testing various methods of building a skeleton control without using data other than those furnished by the photographs, the preference was finally given to the Bagley method of orientation, which will be described later. Once the skeleton control is satisfactorily prepared, the tracing of the photographs becomes comparatively simple. One at a time they were placed under the tracing cloth, oriented by the control points provided by the Bagley method, and traced. For photographs that were materially out of scale, it often became necessary to provide additional control points. By centering the tracing cloth over one such point at a time, the data immediately surrounding it were traced, this operation being repeated at the other control points. The intervening detail was then drawn by distributing the discrepancies due to errors in scale, in proportion to the total errors found in the distances between control points. The discrepancies that had to be adjusted by this process were usually quite small and, by providing a sufficient number of control points, it was possible to obviate the use of proportional dividers.

It is believed that the method herein outlined is superior to the use of the pantograph. The lines produced by the pantograph are somewhat ragged, depending on the skill of the operator, and this requires that they be smoothed out by hand, which is objectionable in that it introduces an added source of error in delineation. The pantograph cannot be used to advantage with tilted

photographs, as the scale is not the same in different parts of the same photograph.

Experiments were made with celluloid sheets, both with and without ground-glass finish, as substitutes for tracing linen, but the latter was found to be the most satisfactory. The celluloid, although superior in transparent qualities, was difficult to manage, because it would not lie flat and, also, because erasures or perspiring hands ruined the ground-glass finish. The celluloid with glossy finish was not suitable for neat work with India ink. In its final form, the map was made in sheets of standard size, 27 by 40 in. over all, comprising areas of about 6½ by 10 miles each.

The Bagley Method of Orientation.—In 1920, Maj. James W. Bagley, Corps of Engineers, U. S. Army, to whom this country is indebted for much of the progress that has been made in the development of aerial photographic surveying, first tested at McCook Field his new "radial line method" of obtaining the correct position of any object shown on two or more aerial photographs. The speaker believes the method should be called the "Bagley Method of Orientation," in honor of its originator. Besides effecting the location of objects by eliminating displacements due to relief and distortion, it facilitates the orienting of the photographs with respect to each other. In the Tennessee River survey, it has proved invaluable in the construction of the skeleton control. The original conception came to Maj. Bagley as the result of his experience with the plane-table system of locating points by intersection, in Alaskan surveys.

The method is based on the assumption that the displacement of objects caused by relief and tilt takes place along radial lines passing through the center of the photograph, and also on the assumption that the center of the photograph, or optical center, coincides with the point on the ground through which a vertical from the center of the lens would pass. It has been demonstrated geometrically by Maj. Bagley that, for all practical purposes, these assumptions obtain in the majority of photographs. In practice, it has been found also that any point near the center may be used without sensible error. Figs. 17 and 18 are reproductions of actual photographs used in the preparation of the skeleton control of the Tennessee River survey. Fig. 19 shows a portion of that skeleton control covering part of the stretch of river between Loudon and Kingston, Tenn., and includes the position of Photographs Nos. 271 and 272 shown in Figs. 17 and 18.

Fig. 19 affords an excellent illustration of the Bagley method of orientation as applied to single photographs within a course, and also to the joining of overlapping courses. The first step in the process is to establish the center of each photograph, which may be done through intersection of the diagonals when no marginal indentures are shown for that purpose. The next step is to locate on each photograph the position of the centers of the adjacent photographs, which is done by reference to the images of natural objects. The successive centers are then connected by straight lines. Fig. 19 shows the position of each photograph in outline, and its center by a heavy circle. The lines connecting the centers have been drawn heavy in order to give them prominence, but, in practice, only the thinnest lines are used, as on them

depends the accuracy with which the photographs are oriented, and any deviation would vitiate the remainder of the work. If it should happen that the center of one photograph cannot be shown in the next, it becomes necessary to supply an auxiliary point. In Fig. 19, a case of this kind appears in Photograph No. 275. Its center did not appear on Photograph No. 276, and an auxiliary point, also located by reference to natural objects, had to be established, as shown. The point selected for this must be common to both photographs and must lie as nearly as possible on the straight line connecting their centers.

After the center points and connecting lines are once established, the next step is to select the so-called control points. These points must be situated so as to be common preferably to three or more photographs and in no case to less than two. For instance, the control points in the upper left of Fig. 18 are common to Fig. 17. Some of the control points in Fig. 19 will be seen to be common to as many as five photographs. Radial lines are drawn from the center of each photograph through the control points, as illustrated in Figs. 17 and 18. The skeleton control is then constructed by placing the photographs, one at a time, under a sheet of tracing cloth, or celluloid, on which is then drawn the centers and connecting lines, and the radial lines to the various control points. Each successive photograph is placed in position by means of its center already located from the previous photograph, and by orientation on the line connecting its center with that of the previous photograph. As the radial lines to the control points are traced and made to intersect, the proper location of these points is thereby automatically established.

It has been found useful to have from nine to twelve control points to each photograph and to locate them away from the centers, and preferably at or near important features to be embodied in the map, such as shore lines of rivers, highways, and fences. This insures the correct position of these features in the skeleton control. If the photographs are free from tilt and are all taken from practically the same altitude, the radial lines will be found to intersect at single points. It will be noted in Fig. 19 that the intersections obtained were satisfactory in most instances and that points common to both courses showed substantial agreement. In a few cases, the radial lines failed to intersect at a point, and a small triangle was formed. Poor intersections of this kind were usually attributable to distortions caused by tilt. In such cases, the true position of the control point was taken as lying in the center of the small triangle.

In the lower tier of Fig. 19, the radial lines are not drawn so as to intersect. Instead, small circles are drawn indicating the actual positions of the control points in the separate photographs. This was done for the purpose of illustrating the discrepancies that were commonly found in the position of such points. The amount of the discrepancy should be measured between the center of the circle and the point of intersection of the radial lines. Measured by the scale of the photographs, it seldom was as much as 100 ft., and this represented the combined effect of altitude and tilt near the edges of the photographs where errors from these sources would naturally be greatest. In Photograph No. 272, Fig. 19, are shown the discrepancies of this kind as

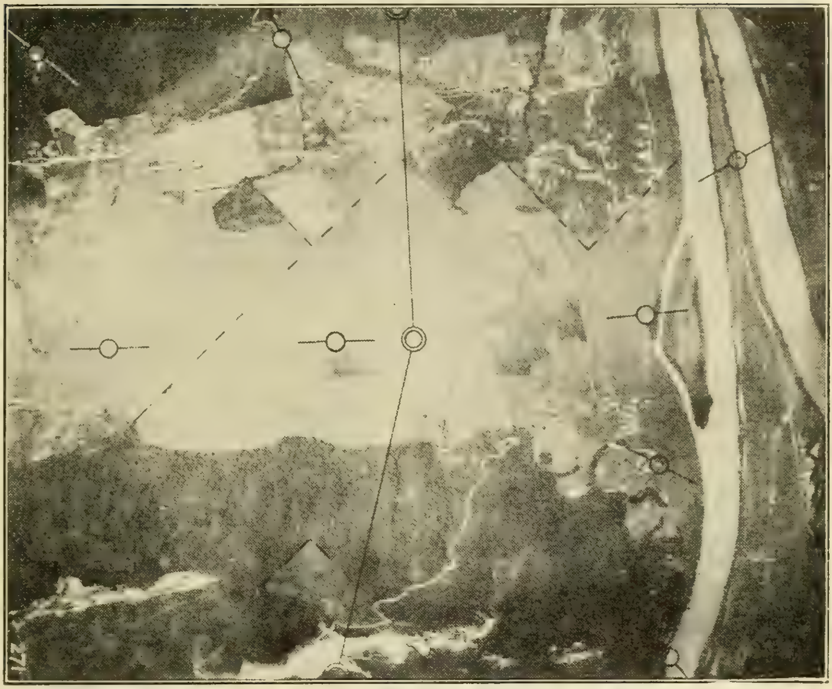

Fig. 17.—Reproduction of Photograph Used in Preparation of Skeleton Control, Tennessee River Survey.

Fig. 18.—Reproduction of Photograph Used in Preparation of Skeleton Control, Tennessee River Survey.

they affected the location of roads and section lines, the former being indicated by double lines and the latter by broken lines. The evidence presented shows the necessity for a systematic procedure such as that outlined to eliminate discrepancies of this kind. Efforts were made in the Chattanooga Office to locate photographs with reference to the continuity of river bank lines, using such lines as the sole form of control. This method was fairly successful when there was no distortion due to tilt, because the surface of the river was, for all practical purposes, a level plane, and points in this plane were not affected by elevation displacements. The Bagley method proved to be superior, however, and was adopted.

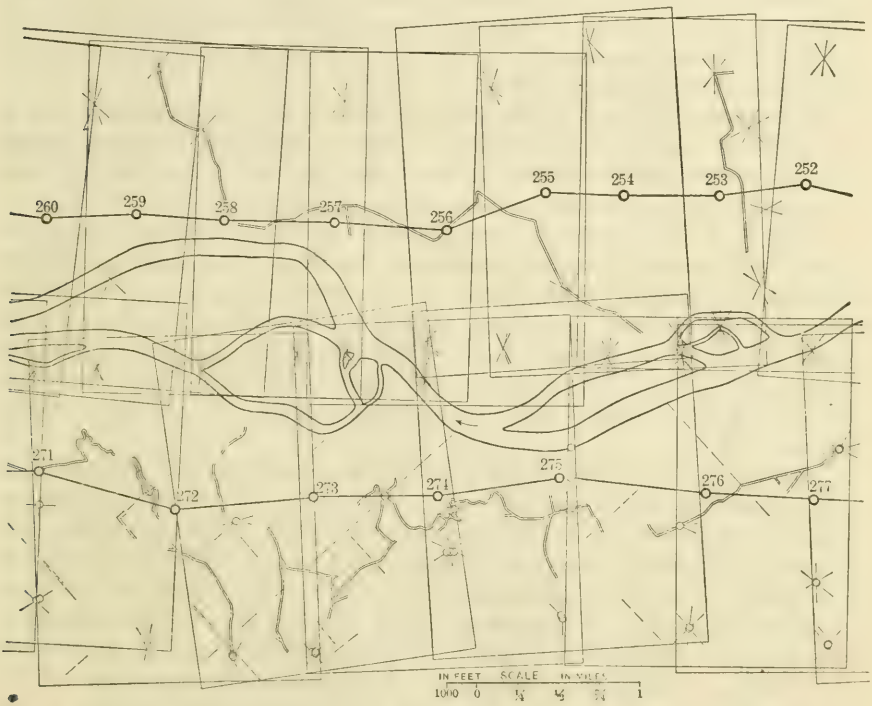

FIG. 19.

Tilted photographs were readily recognized as they would be out of line when platted on the index sheets or in the skeleton control. Thus, in Fig. 19, Photographs Nos. 272, 273, and 275 are probably affected by tilt. Photograph No. 255 is probably similarly affected, but to a lesser degree. In the preparation of the skeleton control, care had to be exercised to guard against errors in scale. Therefore, before beginning such work it was of much value to be able to note the results of the check measurements made in the field. When a series of photographs of practically uniform scale were found, they were platted at once in skeleton form. If an adjacent course of photographs happened to be on a different scale, that course was platted on a separate sheet,

and no matching of the two courses could be undertaken until the proper reduction or enlargement had been made.

In some localities, section lines proved of much assistance in checking the scale of the photographs. It is to be regretted that only a small part of the country was sectionized, and as this had been done prior to 1851, it had become largely obliterated. It is interesting to note, in this connection, the value of the photographs in revealing the remnants of this old system of land lines. In Figs. 17 and 18, the broken ink lines were drawn to mark all plainly visible property lines that were in accord with the sectionizing. Fig. 19 shows, in the lower tier, the character of the information thus made available.

In preparing the skeleton control, it was customary to draw the river banks, highways, and railroads at intervals, because such data assisted in placing accurately the photographs to be traced. Fig. 19 illustrates the extent to which this practice was carried.

It is beyond the scope of this paper to discuss the finer points involved in the use of the Bagley method of control. The experience in Tennessee proved that the method was not difficult to learn, and gave satisfactory results whenever good technique was used and the photographs had ample lap.

Fig. 19 is of interest in showing what to avoid. The two courses of photographs overlap in the region which, in this survey, happens to be of greatest importance, namely, along the river. As the discrepancies due to tilt and elevation displacements are always greatest near the edges, much extra work was entailed in this instance in determining the correct location of the river banks. It would have been better if the aviators had secured the location of the river in the middle of one course of photographs with additional courses on each side.

Ground Control.—The original plans for the survey of the Tennessee River contemplated the use of existing river charts of the Engineer Department as a ground control for the location of the photographs. These river charts were the results of transit surveys made by standard methods, platted to a scale of 1 : 2 000 and reduced by pantograph to 1 : 6 000. Two stadia traverse lines, one along each bank and interconnecting at intervals so as to form a series of closed circuits, furnished the control. With occasional exceptions, these charts were fairly accurate, and afforded reliable checks on the alignment of the photographs. The checks thus obtained demonstrated that wherever ample lap existed between photographs, say, from 50 to 60% in both directions, the map as constructed from aerial photographs by the Bagley method was as accurate as the survey charts, and, in places, the photographic map was the more reliable. The errors that grew out of the skeleton-control method were negligible for the purposes which the map was to serve. The latter consideration was the only criterion by which the sufficiency or insufficiency of the accuracy obtained was judged. Table 5 shows some of the principal check measurements on which the foregoing statements are based.

Maj. Bagley has ascertained that the orientation of a set of photographs possessing at least 50% lap, can be carried in the direction of flight, by his method, over distances as great as four times the width of the area photographed, with satisfactory results. In the Tennessee River survey, the width

was never less than two photographs, or 3 miles wide, allowing for 50% lap, and was usually much wider than that. As a 27 by 40-in. sheet covered at the most about 10 lin. miles of map, the chances of accumulating an appreciable error within the confines of one sheet of standard size were well within the limits stated.

TABLE 5.

Description of distances.	1909 survey; scale, 1 : 6 000, in feet.	New map; scale, 1 : 15 000, in feet.
Out-to-out of north and south loops near Post Oak Island	14 630	14 375
Width of Post Oak Island	2 420	2 450
Length of Post Oak Island	6 500	6 560
Across neck, west of Post Oak Island	3 800	3 750
Across neck, west of Post Oak Island, including island and river	7 520	7 438
Foot of Post Oak Island to foot of Prater Island	18 530	18 562
Across neck at Keller Bend	4 080	4 125
Across widest part of Keller Bend	4 890	4 850
Out-to-out bend at Prater Island to bend west of Cox Island	17 700	17 750
Perpendicular to Louisville Ferry	8 590	8 588
Foot of Prater Island to Point A (near Concord)	20 375	20 375
Across bend south of Concord, Points A to B	7 610	7 460
Across neck south of Concord, out to out	3 880	3 850
Across neck south of Concord, inside to inside	2 450	2 440
Point *O* near Concord, to Point *P*, near Chota Island	19 770	19 900
Point *P* to Louisville Landing	30 730	30 750
Foot of Prater Island to Louisville Landing	11 270	11 250

Cost.—The field work on the Tennessee River survey was conducted over a period of 8 months and was stopped on June 30th, 1922, because of lack of appropriation. In all, 80 lin. miles of the valley of the Tennessee River, measured along the thread of the stream, had been covered. An average cost per square mile for the entire survey cannot be obtained as much of the early work was experimental. Weather conditions, the seasonal state of the vegetation, and the character of the topography introduced wide variations. Toward the latter part of the work, when a regular routine had become established, the indications were that the cost per square mile was about as follows: All field costs, inclusive of field drafting, less than \$50; preparation of skeleton control, about \$1.25; and final tracing, \$3.50. The cost of the aerial work, not including depreciation of equipment and overhead expenses, was about \$6 per sq. mile. On this basis, the total cost is about \$61 per sq. mile.

Errors in Photographs.—Much apprehension has been expressed concerning distortion and displacement in aerial photographs. The speaker's experience leads him to the belief that such apprehension is frequently the outcome of lack of familiarity with the practical utilization of aerial photographs, and that the net result of such errors is likely to be exaggerated. In aerial photography, as in ordinary ground surveying operations, instrumental errors are of several kinds and must constantly be guarded against. However, the aerial method being largely a mechanical procedure, is freer from the vexatious human blunders so common in ordinary surveying, blunders which are not easily eliminated, and which in the best accepted practice have to be disposed of by so-called adjustments. The photographic errors in the work done on the Tennessee River were either readily detected and allowance made therefor, or

were so small as to be of no importance to the purpose of the final map. The troubles that required the most vigilance were:

1.—Differences in scale of photographs due to the aviators not flying at the proper altitude. Errors of as much as 1% in scale were frequent, but usually such errors were detected readily by comparison with overlapping photographs and through the check measurements made by the field men, as previously described, and also occasionally by reference to section lines.

2.—Displacement of objects due to differences of elevation of the terrain is most troublesome near the edges of a photograph. With this in mind, the areas selected for contouring were made to occupy, as nearly as practicable, the center of the photographs. The outlines of the Tennessee River were found to be quite free from displacement, because its water surface was practically a horizontal plane. This was the more fortunate as the correct location of the river not only was of prime importance, but also made possible a close comparison with the earlier ground surveys. The displacement of objects away from the river on ground 200 to 300 ft. above the river level rarely amounted to as much as 100 ft. laterally, and, ordinarily was much less. As such displacement was always in a radial direction away from the center of a photograph, usually little doubt existed as to its nature and effect. The radial method of locating control points, described previously, proved satisfactory in eliminating displacements, which form of error, although the most common to be dealt with, was the least difficult of correction.

3.—Distortion is a term often misapplied to displacement, but relates to entirely different sources of error. True distortions are caused by the tilting of the camera at the instant of exposure; by sudden gyratory movements of the plane; and by imperfect action of the focal plane shutter. Occasional instances were found of these troubles, which would have been quite difficult to eliminate had it not been that, through the use of overlapping photographs, the distorted photographs could be corrected or discarded.

The amount of tilt in aerial photographs is much less than is commonly supposed. In *Information Circular No. 184* of the Air Service are given the results of tests from which it appears that about 29% of the photographs tested showed a tilt between 0° and 0°30′; 64.5% between 0°30′ and 1°; and 6.5% between 1° and 1°30′. A tilt of 3° or more is of rare occurrence. The errors introduced by tilting within the limits stated, affect the position of objects mainly in a radial direction with reference to the center of the photograph, the angular discrepancy being extremely small.

Overlap.—The experience gained on the Tennessee River survey points to the necessity of securing a generous overlapping of the photographs. A lap of about 60% in the direction of flight and of about 50% between courses, is needed, in order to:

(*a*) Construct a rigidly accurate skeleton control;
(*b*) Correct the displacement of objects;
(*c*) Eliminate distortion;
(*d*) Bring out clearly important details by photographing them from more than one angle of view; and
(*e*) Get the full benefit of the remarkable stereoscopic properties of aerial photographs.

Applicability.—The method of aerial photographic mapping, as described, is adapted to any region of moderate relief, regardless of its elevation above sea level. Deep canyons and precipitous mountains introduce troublesome amounts of displacement, and, therefore, aerial photography is not well suited to the mapping of such features. However, it would be practicable to use it in reservoir surveys in mountainous country for the reason that reservoir sites always occupy valley bottoms, and no large part of the adjacent mountains need be shown. This is also true of irrigation projects, because the lands to be irrigated are usually of low relief even though situated in a mountainous region.

The method possesses many advantages in studying routes for power-transmission lines through rough or timbered country by eliminating costly preliminary surveys. In such studies, the bare photographs, unassembled in mosaic or map form, will prove helpful in showing all those features which enter into the consideration of locating such lines, not the least being the property lines and the roads and trails required for construction purposes and for patroling. The stereoscope will solve many questions regarding the topography of any proposed route. No ordinary survey or map will furnish all this information so completely or compactly, nor could any surveyor hope to secure so much information at any reasonable expenditures of cost and time.

A valley or canyon presenting a series of alternative sites for dams is best studied by means of aerial photographs. This will save much of the ground surveying ordinarily required in selecting the best site, and the survey of the latter will be facilitated by having the aerial photographs available for mapping purposes. These are only a few of the many uses of aerial photographic surveying that have suggested themselves. The results obtained on the Tennessee River and elsewhere indicate that the time is not far distant when aerial photographic surveying will displant many of the time-honored methods of surveying and map making now in use. Much is being done to improve aerial and photographic equipment, and great progress may be expected, especially if the modern airplane should be superseded by a type of aircraft better suited to photographic work.

Acknowledgments

The survey of the Tennessee River was made under the general direction of Maj. Harold C. Fiske, Corps of Engineers, U. S. Army, with the speaker in immediate charge. The general plan which was followed, and which has been described, was first conceived by Maj. Fiske. It is only fair to state that it was due to his resourcefulness and keen personal interest in the survey and the development of its details, that it was possible to accomplish so much with the small funds available. The speaker takes pleasure in acknowledging his indebtedness to Maj. James W. Bagley, Corps of Engineers, U. S. Army, for many valuable directions and suggestions. The Army Air Service deserves commendation for the co-operation extended and for the courteous and accommodating spirit displayed by the officials, as well as for the excellent aerial work done by the aviators. A tribute is also due the field survey personnel for their work.

HYDRO-ELECTRIC DEVELOPMENTS ON THE PACIFIC COAST

By John D. Galloway,* M. Am. Soc. C. E.

Synopsis

This paper deals with the general characteristics of power systems in the Pacific Coast States. A short review of the historical development is given, including the increase in size of generators and the parallel development of impulse wheels and turbines, together with the evolution of transmission lines and line potentials. Consideration is given the elements of design and the limitations of impulse wheels and turbines, the tendency toward larger units and the reasons therefor, and the present stage of development of other parts of the power system. The paper also refers generally to the variation in demand of various power systems, the annual increase in demand, the relation of steam plants to water-power plants, and the special relation of hydro-electric plants to irrigation.

Historical

Before discussing some of the problems that enter into the generation, transmission, and distribution of hydro-electric power on the Pacific Coast, a review of the historical development of the art may be of interest as illustrating its rapid growth and the evolution of the design of its various elements.

The first long-distance transmission of energy by electricity was accomplished in Italy in 1886, when single-phase current was transmitted 17 miles, at 2 000 volts, from the Cerchi-Tivoli steam plant to Rome. In 1892, the plant at Tivoli was enlarged by the addition of four 250-kw., three-phase generators driven by hydraulic turbines, and three-phase current was transmitted at a line pressure of 10 000 volts.

In September, 1891, a three-phase transmission was installed from Lauffen to Frankfort, Germany. This line was 110 miles in length and was operated at 12 000 volts.

The first transmission system in America was that built at Oregon City, Ore., on the Willamette River, in 1889. Energy generated by six turbine-driven, 80-kw., 4 000-volt, single-phase generators was transmitted, at the generator voltage, to Portland, Ore., a distance of 13 miles. This development was followed by the building of several small, single-phase plants in the West, namely, at Ames, Colo., and at Pomona, Calif., in 1890; at San Bernardino, Calif., in 1891; at Walla Walla, Wash., and at Bodie, Calif., in 1893.

The first three-phase plant in America was that at Mill Creek, Calif., where two 250-kw., 2 400-volt, three-phase generators were installed in 1892 and placed in operation on September 7th, 1893, delivering power 23 miles to Riverside, Calif., at a line potential of 10 000 volts.

* Cons. Engr., San Francisco, Calif.

The superiority of three-phase current over single-phase or two-phase current was soon realized, having been indicated by Tesla, Ferraris, and Bradley as early as 1887. After the Mill Creek plant had been placed in operation, three-phase systems became the standard. Many plants were built in the West during the period, 1895-1900. By the end of 1900, transmission lines had reached a length of 86 miles, from Mill Creek to Los Angeles, Calif. The highest line potential, 40 000 volts, was used on the Provo-Murcur line in Utah.

It is unnecessary for the purposes of this paper to recite the details of the progress, except to note that line potentials were raised, successively, to 60 000 volts on the Colgate-Oakland line and on the Electra-Oakland line, 150 miles, in 1901; to 100 000 volts on the Las Plumas-Oakland line, 155 miles long, in 1908; and to 150 000 volts on the Big Creek-Los Angeles line, 241 miles, in 1913; and two lines are now being built in California to operate at a line potential of 220 000 volts. A more detailed historical paper was contributed by the speaker to the International Engineering Congress at San Francisco, Calif., in 1915.*

In the evolution of hydro-electric power systems, the development of electric generators is a striking example of rapid growth in size and design in response to a demand. The first machines were small—only 100 to 200 kw.—but the advantage of larger units was soon recognized, and such units were built, successively, until in October, 1895, 3 730-kw. generators, projected in 1893, were placed in operation at Niagara Falls. These remained the largest units until in 1904, a 5 000-kw. unit was placed in operation at de Sabla, Calif. In 1905, a 7 500-kw. unit was placed in service at Niagara Falls; in 1907, four 8 500-kw. units were placed at Stanislaus, Calif.; and, in 1908, four 10 000-kw. units were installed at Las Plumas, Calif. The 10 000-kw. size remained, to a certain extent, standard for a few years, but in 1913, two 12 500-kv-a. units were installed at Drum, Calif., and four 17 500-kv-a. units at the two Big Creek plants. The 17 500-kv-a. units were not exceeded in the Pacific Coast States until 1921, when the units of Big Creek Plant No. 8, of 22 500-kw., began operation. At the present time, three 25 000-kw. units are being installed at Big Creek Plant No. 3, of the Southern California Edison Company. The largest units now in operation on the Pacific Coast are the two 35 000-kw. units at Pit River Plant No. 1 of the Pacific Gas and Electric Company, one unit of which was placed in service in September, 1922.

Parallel with the development of generators and their increasing size was that of the prime movers, turbines, and impulse wheels. Both these devices were in service before they were used to drive electric generators, but since the two have been used in conjunction, a rapid improvement in efficiency, design, and construction of prime movers has kept pace with the similar development of electric generators and has made the latter possible.

The original small electric plants serving some small industrial unit, such as a street railroad, a mine, or a factory, have grown, during a quarter of a

* *Transactions*, International Eng. Congress, San Francisco, Calif., 1915, Vol. VII, Paper 146.

century, to large systems serving millions of people and with interconnected lines extending more than 1 000 miles. No limit has been reached either in size of units or length of transmission lines, although a line potential of 220 000 volts is approaching the ultimate practicable pressure of possibly 1 000 000 volts.

Elements of Design

In a previous paper,* the speaker discussed the elements of the design of hydro-electric power plants, and the detail will not be repeated here. Some reference is made, however, to design as related to the general subject of hydro-electric systems.

In the paper referred to, the limitations of impulse wheels and turbines were examined. A gap exists between the two, that has not been closed. This may be stated generally, that impulse wheels, on account of efficiency and design, are limited to a single nozzle on each wheel, and each generating unit is limited to two wheels, one on each end of the shaft. The limiting relation between size of jet, diameter of wheel, and velocity of water, when taken in connection with the other two factors, places a maximum limit to the size of units driven by impulse wheels. The 12 500-kv-a. units at Drum, driven by two single-nozzle, 8 500-h. p. impulse wheels at 360 rev. per min., under an effective head of 1 345 ft., and the 17 500-kv-a. units at Big Creek Plant No. 2, driven by two single-nozzle, 10 000-h. p. impulse wheels at 375 rev. per min., under an effective head of 1 780 ft., represent about the maximum sizes for such units at those heads. Any larger impulse-wheel-driven units would require higher heads, a greater number of wheels on one shaft, or more nozzles on one wheel. The last device, after trials, has practically been discarded. More nozzles to one wheel or more than two wheels to one shaft complicates the governing mechanism, and this has not been solved in a satisfactory manner.

The turbine as a prime mover, however, has the defect that it is not applicable to small or medium sized units (2 000 to 5 000 kw.), at high heads, when restricted by limiting generator speeds. On a low-head unit, less than 200 ft., the turbine is the only prime mover for units of 5 000 kw. and more. On horizontal shaft units, two runners, and on very low-head plants, four runners, have been used. On medium-head plants (200 to 750 ft.) single-runner turbines are available for most units built in the last ten or twelve years. Examples of smaller sizes with single runners are cited in Table 6.

TABLE 6.

Location.	Horse-power of turbine.	Effective head, in feet.	Speed, in revolutions per minute.
Salmon River N. Y.	10 000	245	375
Snoqualmie Plant No. 2, Wash.	12 500	270	360
Nisqually, Wash.	8 000	425	450
Coleman, Calif.	7 000	487	450
Centerville Calif.	9 700	565	400
Carp River, Mich.	4 000	580	720

* *Transactions*, Am. Soc. C. E., Vol. LXXIX (1915), p. 1000.

The best use for the turbine is found in the larger sized units installed in recent years, of which the list in Table 7 gives some examples of low and medium sizes of units with single runners.

TABLE 7.

Location.	Horse-power of turbine.	Effective head. in feet.	Speed, in revolutions per minute.
Keokuk, Iowa	10 000	32	57.7
Canadian Niagara Falls	10 000	130	250
Shawinigan Falls, Que	18 500	145	225
Laurentide Power Co., Que	20 000	76	120
White River, Wash	18 000	440	360
Las Plumas, Calif	18 000	465	400
Big Creek Plant No. 8	31 500	729	428
Big Creek Plant No. 3	35 000	740–800	428
Pit River Plant No. 1	40 000	450	257
Canadian Niagara Falls	60 000	....	....

Thus, with the use of larger units, the turbine is being utilized under higher heads. There is no reason why turbines built with cast-steel scroll cases should not be used under heads up to 1 000 ft., and possibly higher. For higher heads, the impulse wheel remains the only prime mover, and, therefore, where a power station might have large size units, if turbines could be utilized, the use of impulse wheels would materially reduce the size. No limit in size has been reached for turbine-driven units. A single unit of 70 000 h. p. is under construction for Niagara Falls.

The preceding discussion is given to illustrate by examples the limitations of turbines and impulse wheels and also the trend of present practice. As units have grown larger, the turbine has usurped the domain of the impulse wheel for heads up to 750 ft. The growth in size of units has coincided with the increase of power systems. The principal reasons for this result may be stated, as follows:

(*a*) Increased efficiency of the unit.

(*b*) Relatively less first and operating cost.

(*c*) Less cost of power station building.

(*d*) Increased length and potential of transmission lines requiring larger charging current capacity in single-generator units.

(*e*) The increased load on power systems, with greater total generating capacity at several interconnected stations, allowing larger units to be used at any one station.

At present, the largest single units in the West are the two 35 000-kv-a. generators operated by single-runner turbines at Pit River Plant No. 1, of the Pacific Gas and Electric Company in California. Reference may also be made to the use of vertical shaft units that now represent a type possessing many advantages over those with horizontal shafts. The vertical shaft units have been made possible by the use of the Kingsbury bearing, or other bearings depending on the same principle. The entire rotating element, consisting of the turbine runner, the shaft, and the generator rotor, are suspended on the

bearing which is sustained on the top of the generator frame by a spider. This bearing has eliminated the use of the older solid disc bearing, or the roller bearing, both of which required oil under heavy pressure, with the resulting expensive system of pumps.

The principal advantages of the vertical unit over the horizontal may be stated, as follows:

(1).—A straight draft-tube is generally possible, giving better discharge and higher efficiency.

(2).—The turbine runner is more accessible.

(3).—A thrust-bearing is not required.

(4).—The generator is in a better position for ventilation and uniform atmospheric conditions and is also more accessible for repairs. The rotor can be lifted from the unit without disturbance of other parts.

(5).—The generator can be placed on an upper floor above high water.

Of the later developments in the prime movers may be mentioned the governor-operated, synchronous by-pass on impulse wheels, that has replaced the older deflecting nozzle, and, on turbines, the governor-controlled, direct-connected servo-motors for operating the turbine gates. Direct-connected, synchronous by-passes have been developed in the last fifteen years. These by-passes obviate, to a great extent, the danger to the penstock and turbine from surges due to interruption of the current. A recent device places the rotating element of the governor on the turbine shaft, thus eliminating belt connection. On many later units, the exciter units are direct connected to the generator, being placed on an extension of the shaft and replacing the older exciter units with their water and electric-motor drives. This latter is not a new device, but it became possible to use it as the power systems became larger.

Coincident with the development of larger turbines has been that of butterfly or pivot valves that are practically water-tight. Valves of the balanced piston or Johnson type, with the pivot-valves, have replaced the older gate-valves that became impracticable in large sizes under high heads.

Of the other accessories of power plants, the developments of the last five years have brought little change. American-made welded-steel pipe for penstocks in large sizes is a more reliable article than that formerly imported from Germany. Conduits are made more permanent, and concrete-lined tunnels are replacing the open ditches and timber flumes of the past. The theory of surges in pressure conduits and the design of surge-chambers and their installation at the junction of conduit and penstock has become a regular feature of power plants on the Pacific Coast.

At the power plant, all transformers, high-tension switches, and bus-bars were placed at first inside the building. During the last few years, however, there has been an increasing tendency to place this apparatus outside the building, especially where line potentials of more than 100 000 volts have been used. This practice, of which the Southern Sierras Power Company was one

TABLE 8.—DAILY AVERAGE ENERGY OUTPUT, IN KILOWATT-HOURS, AND PERCENTAGE OF ANNUAL MEAN.

Month.	Washington Water Power Company.		Puget Sound Power and Light Company.		Pacific Gas and Electric Company.		San Joaquin Light and Power Company.		Southern California Edison Company.	
	Daily average, in kilowatt-hours.	Per-centage.	Daily average, in kilowatt-hours.	Per-centage.	Daily average, in kilowatt-hours.	Per-centage.	Daily average. in kilowatt-hours.	Per-centage.	Daily average, in kilowatt-hours.	Per-centage.
January........	984 430	96.0	1 196 330	104.1	3 964 000	97.2	778 960	71.8	2 297 360	78.5
February......	969 590	94.5	1 177 020	102.4	3 857 000	94.5	765 100	70.5	2 052 010	70.0
March.........	977 190	95.3	1 182 710	103.1	3 806 000	93.4	821 800	76.8	2 464 890	84.3
April......	925 190	90.3	1 137 340	99.0	3 937 000	96.5	1 213 120	112.0	3 085 780	105.3
May............	879 980	85.8	1 041 040	90.8	4 290 000	105.0	1 172 890	108.1	2 865 560	98.0
June...........	973 700	94.9	1 064 120	92.7	4 430 000	108.5	1 258 130	116.0	3 309 960	113.0
July............	1 011 440	98.7	1 007 350	87.7	4 284 000	104.9	1 369 600	126.0	3 575 340	122.0
August,.........	1 112 690	108.6	1 078 000	93.9	4 277 000	104.8	1 360 160	125.2	3 548 890	121.0
September.....	1 076 040	104.9	1 159 530	101.0	4 133 000	101.2	1 193 580	110.0	3 428 730	117.0
October........	1 127 680	109.9	1 186 970	103.2	4 048 000	99.2	1 035 760	95.5	2 855 020	97.5
November......	1 155 080	112.7	1 274 420	111.0	3 973 000	97.4	1 051 630	97.0	2 911 240	99.5
December.....	1 110 430	108.2	1 277 890	111.2	3 974 000	97.4	984 940	90.8	2 744 840	93.8
Mean...........	1 025 690	100.0	1 148 490	100.0	4 081 000	100.0	1 085 410	100.0	2 932 630	100.0
Annual load factor........	61%		48.8%		63.6%		52.9%		64%	

of the pioneers, is rapidly extending. On the new 220 000-volt lines of the Pacific Gas and Electric Company, all high-tension apparatus is placed in the open.

Transmission lines have been increased in length and in line potential. Probably the longest transmission is that of the Southern Sierras Power Company to Yuma, Ariz., more than 600 miles. Steel towers and suspension insulators have become standard. The long lines, high potentials, and large amounts of energy transmitted now require large installations of condensers at the receiving end, an important element in the cost.

Characteristics of Western Power Systems

At the beginning, little was known of the various factors that enter into the generation, transmission, and distribution of hydro-electric power. As the systems extended and a wider range of industries were supplied with power, the characteristics of such industries became better known. The integrated result of load variation, expressed as an annual load factor, or ratio between the yearly average and maximum or peak load, measures, in one way, the demands on a power system. The annual load factors of several large Pacific Coast systems are given in Table 8.

Another important element in the systems, however, is the seasonal variation in energy output or demand, which differs widely on different systems, especially in California. The rainless period, extending over about seven months, causes the Sierra Nevada streams to fall in summer to a small proportion of the average flow. Again, many industries, such as those that depend on agriculture, are subject to wide variation in power demand, coming from irrigation-pumping, fruit-packing establishments, and coincident activity, occur at a time of year when the streams are low, and thus require that the power deficiency in natural stream flow be made up by stored water or by steam-generated energy.

Table 8 gives the total energy generated by months, but expressed as a daily average for the month, for two companies in Washington and three in California. Purchased energy is included, as it all represents a demand on the company. The year 1921 was chosen as representing the latest information, and also because, on most of the systems, there was not much increase in demand. A column of percentage departures from the mean is added to express the variation in demand. Fig. 20 shows the percentage variation graphically.

There is an error in Table 8 and Fig. 20, as the kilowatt-hour output necessarily contains the increase in demand that comes to all growing systems. This, however, is a better representation of conditions that will prevail for a considerable time. Attention is called to the range of power demand. Central California, as represented by the San Joaquin Light and Power Company, in the San Joaquin Valley, a community predominantly agricultural, and Southern California, represented by the Southern California Edison Company, have a greater annual variation in energy output than the companies of Northern California or Washington. The examples are given as representing Pacific Coast conditions and as what may be anticipated elsewhere under

similar conditions. It should be noted that the system peak does not necessarily occur in the month of maximum energy demand. The systems discussed serve a large variety of industries, of which mining and agriculture comprise a fairly large part. Lighting requires a relatively small part of the energy sold.

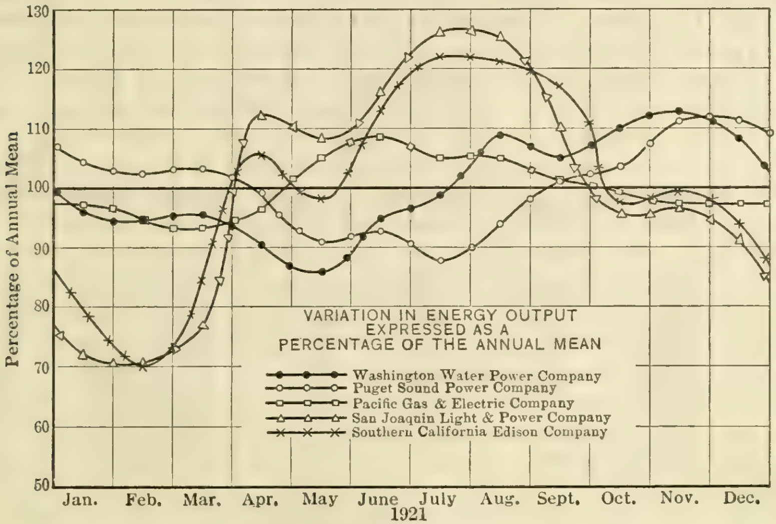

FIG. 20.

Increase in Demand.—The development of hydro-electric power during the last ten years has been on a firmly established basis. It is possible to take the records of growth for that period and to determine with reasonable certainty a rate of growth that will enable one to forecast the future demand for ten or fifteen years to come. Different localities exhibit strikingly different rates. Again, the rate of increase in demand has not been uniform over the last ten years, due largely to the World War and the resulting industrial changes. The average rate, expressed as an annual compounding rate, over the entire period will give a fairly good index of future growth. Table 9 is given to show conditions in California, where the rate for the State is 11.1 per cent.

Table 9 shows an increase in nine years, as follows:

Water.—From 1 068 000 000 to 2 493 000 000 kw-hr., or, approximately, 134% which is 9.9% compounded annually.

Steam.—From 334 000 000 to 1 124 600 000 kw-hr., or, approximately, 237% which is 14.4% compounded annually.

Total.—From 1 402 000 000 to 3 617 600 000 kw-hr., or, approximately, 158% which is 11.1% compounded annually.

It also shows that the steam output ranged from a minimum of 15.2% to a maximum of 36.2% of the total output.

An examination of Table 9 which was prepared by A. H. Markwart, M. Am. Soc. C. E., shows a wide variation in power demand from year to year. Similar tables show for Northern California an annual compounding rate of

6.96%; for the Pacific Gas and Electric Company, a rate of 7.44%; for the Great Western Power Company, 7.07%; and a rate of about 18% for Southern California.

TABLE 9.—KILOWATT-HOUR OUTPUT FROM WATER AND STEAM, 1911 TO 1920, INCLUSIVE, FOR STATE OF CALIFORNIA, BASED ON RAILROAD COMMISSION RECORDS FOR ALL PUBLIC UTILITIES, INCLUDING CITY OF LOS ANGELES AND OTHER SMALLER MUNICIPAL PLANTS.

Year.	WATER.		STEAM.		TOTAL.		Steam, in percentage of total.
	Millions of kilowatt-hours.	Percentage of increase.	Millions of kilowatt-hours.	Percentage of increase.	Millions of kilowatt-hours.	Percentage of increase.	
1911.........	1 068.0	.....	334.0	.....	1 402.0	....	23.8
1912.........	1 143.0	7.0	445.0	36.2	1 598.0	14.0	28.5
1913.........	1 263.9	10.6	715.2	57.2	1 979.1	23.8	36.2
1914.........	1 746.0	38.1	356.3	50.2 (Dec.)	2 102.3	6.2	16.9
1915.........	1 816.8	4.1	394.5	10.7	2 211.3	5.2	17.8
1916.........	1 992.2	9.6	357.1	9.5 (Dec.)	2 349.3	6.2	15.2
1917.........	2 142.5	7.5	495.5	38.8	2 638.0	12.3	18.8
1918.........	2 254.3	5.2	710.7	43.4	2 965.0	12.4	24.0
1919.........	2 241.3	0.6 (Dec.)	993.6	39.8	3 234.9	9.1	30.7
1920.........	2 493.0	11.2	1124.6	13.2	3 617.6	11.8	31.1
Total increase....	1 425.0	134.0	790.6	237.0	2 215.6	158.0	....
Annual increase....	....	9.9	....	14.4	......	11.1	....

It might be questioned as to whether this rate of growth is temporary only and whether the market will not be soon saturated. The only way in which this could be ascertained was to examine the rate of increase of population in the United States and to compare it with the growth of standard industries, all expressed as a compounding annual rate. These statistics are given in Table 10.

TABLE 10.—INCREASE OF CERTAIN ITEMS IN THE UNITED STATES.*

Item.	Period.	Compound annual percentage rate.
Population of United States..........................	1900–10	1.95
" " " "	1910–20	1.38
Coal produced..	1900–09	8.78
" "	1909–19	5.71
Pig iron produced......................................	1901–09	6.15
" " "	1909–19	4.18
Steel and iron produced..............................	1900–10	8.60
" " " "	1910–20	4.10
All United States manufacturing....................	1904–14	5.06
Post Office Revenues...................................	1900–10	8.16
" " "	1910–20	6.90
Bank clearings, Pacific Division....................	1911–19	13.40
California manufacturing..............................	1904–14	6.86

* From U. S. Statistical Abstract.

It will be noted that even in the old established industries the annual compound rate of increase is from three to four times the similar rate of increase of population.

The deductions from the study are that, for a long time to come, the power demand on the Pacific Coast may be expected to increase at an annual compounding rate of from 5 to 7%, and much more in some localities. It is probable that by 1930, the annual energy output in California, will exceed 10 000 000 000 kw-hr.

Relation of Steam to Hydro-Electric Power

A proper appreciation of the relation of the steam plant to the water-power plant has arisen with the development of power systems. It might seem at first that when a sufficient amount of generating capacity in the water-power plant had been built, there would be no need of a steam plant. Circumstances, however, have determined otherwise. Everywhere on the Pacific Coast, the hydro-electric plants are situated in the mountains, more or less remote from the cities. Possibly the only exception is at Spokane, Wash., where the Falls of the Spokane River within the city makes it unnecessary for the Washington Water Company to carry any of its load on steam. The opposite extreme is found in California, where transmission lines are 150 to 250 miles long from power plants to load centers. Steam plants, located in large cities, have been built, either as safety reserves or to furnish part of the energy.

The functions of the steam plant, acting in its proper relation to the hydro-electric plants, may be segregated under five general divisions:

(*a*).—As a reserve in case of interruptions to the hydro-electric system. In some cases, as in San Francisco, due partly to the situation, the steam reserve carried by the Pacific Gas and Electric Company exceeds 75% of the load.

(*b*).—To generate a substantial portion of the energy output. Fuel costs are such, however, that, with the average installation prices of hydro-electric systems, energy can be developed cheaper by water than by fuel. In California, however, the abundance of cheap fuel oil in the past, ranging in price from 50 to 60 cents per bbl. at the plant, equivalent to good coal at $2.50 per ton, resulted in the building of numerous large steam plants. The capital charges per kilowatt were considerably less and the energy costs were also less. The time of low priced oil passed, and power companies found their energy costs suddenly raised. This has resulted in an extensive program of hydro-electric development. With oil at $1 per bbl. or more, steam-generated energy is too costly.

(*c*).—To generate energy to carry some of the system load over a period when all the water-power plants are loaded and before the demand increases to a point where the large initial cost of a modern water-power plant is justified.

(*d*).—To generate energy in years of extreme low water. Reservoirs, as a rule, can be built to equalize stream flow during most years, but, at times, a season occurs when the stream flow is much below normal. In such cases, the steam plant makes up the deficiency.

(*e*).—To carry a fair proportion of the peak load. In one respect, this is the most important function of the steam plant. The longer the transmission line, the more important does this function become. The maximum peak load

of a year occurs only once and may last for only ½ hour. Other peak loads of other days or months are not as great. If dependence is placed on the water-power plant alone, all equipment, including long transmission lines, must be installed to carry a power peak, the energy content of which is negligible.

In this case, the steam plant can be arranged to carry from 20 to 25% of the peak, without generating a great amount of energy. This arrangement is beneficial in many ways. Besides saving capital costs in regulating reservoirs, penstocks, hydro-electric generating units, and transmission lines, it raises the load factor on such plants and at the steam plants places the units in service each day. In many cases, the power factor of the system is raised by the operation of the steam plant generators.

The characteristics of each power system and the price of fuel will determine the amount of peak load to be carried and the energy generated at each type of plant. The peak to be carried by steam will range from 10 to 25% of the total. The energy output will depend on the shape of the peaks and the relation of the maximum peak to other average peaks, and may range from 2 to 10% of the annual energy output of the system. Thus, on the average system in the West, the daily load factor on the water plants can be raised from about 60% to from 70 to 85 per cent. The daily load factor on the steam plants will be low, ranging from 25 to 35 per cent.

A diagram, Fig. 21, of a daily load curve, divided between steam and water plants, is given to illustrate this subject.

The Relation of Hydro-Electric Plants to Irrigation

Irrigation is practiced in many parts of the Pacific Coast and produces in hydro-electric systems a large part of the excess power demand of summer. In many cases, especially in California, the same stream that furnishes power, is used for irrigation after it reaches the valley lands. Practically, all the important rivers that descend each slope of the Sierra Nevada are thus used.

There is an apparent conflict between the two uses of water. Power demands a fairly uniform flow throughout the year. Irrigation demand varies between wide limits, ranging from 1 or 2% in some months to as much as 20 or 22% of the total seasonal quantity used. During two or three months of the year, there is no irrigation, and then reservoir gates are closed to store water for the next year.

The solution of this problem is found in the difference in reservoir location. Power requires that water be stored near the head-waters of rivers, in order to take advantage of as much head as possible. For irrigation, however, the reservoirs are needed near the exit of the river from the mountains, in order to obtain the greatest tributary water-shed. Whatever water is released from power storage reservoirs during the irrigating season is of benefit to irrigation, passing directly to the lands. Water released for power during the non-irrigating season can be retained in the irrigation reservoir for use the next season, and thus insures against a failure of irrigation water for a possible future deficient flow of the stream. The irrigation reservoir becomes, in effect, a re-regulating reservoir, changing the stream from the character given it by power regulation to one serving irrigation.

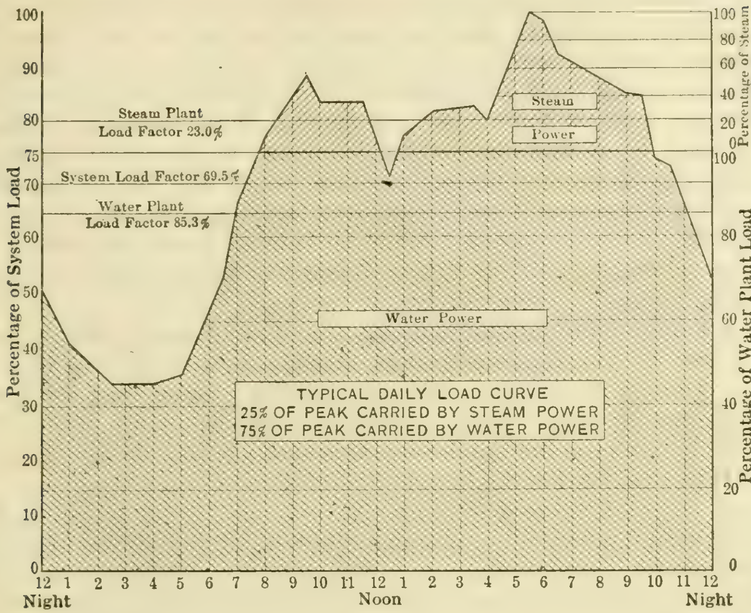

FIG. 21.

These general relations are illustrated in Fig. 22, which shows a hydrograph of a typical California stream, a power demand curve, and an irrigation demand curve, based on conditions in Central California. No fixed rule can be given for solving such problems. Each case must be solved by itself, taking account of the physical characteristics of the stream, the reservoirs, the amount and variation in demand for power, and the amount of irrigation, with its characteristics of use of water, crops, etc.

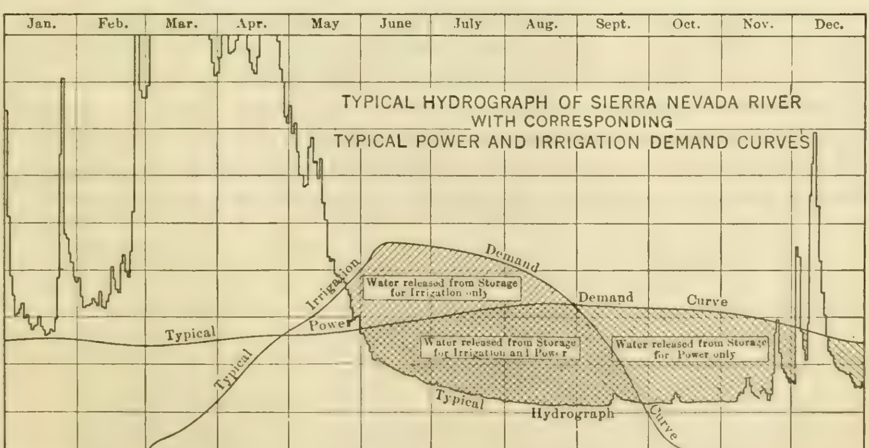

FIG. 22.

A secondary relation between power and irrigation occurs in hydro-electric plants built as adjuncts of irrigation reservoirs. High dams are being built as irrigation storage reservoirs, and this makes possible the development of some power. As the water is used subject to the irrigation demand, the energy output varies widely. At times during the peak of the irrigating season, a very large amount of power is available, but as the duration of this output is short, possibly one or two months, there can be no sale for the maximum amount. Possibly one-third would represent a fair proportion of the maximum possible power to be developed. After the irrigation peak has passed, the power falls off rapidly, owing to decreased irrigation demand and to decreasing head in the reservoir.

These special characteristics make the sale of such power a difficult problem. If used by the irrigation district, that organization must build steam plants to carry the load during the non-irrigating season. If the power is sold to the nearest power system, that system must be capable of absorbing the block of summer power or otherwise it cannot purchase the power. Each case must be considered by itself.

A case in point occurred in connection with the Merced Irrigation District in Central California. In planning the works of that district of 186 000 acres, the speaker planned a reservoir with a capacity of 250 000 acre-ft. on the Merced River. The dam, about 300 ft. high, made possible a power plant of 30 000 kw. and the sale of the energy to the San Joaquin Light and Power Company. The load curve of that Company permitted the absorption of this special block of energy, because the pumping of water for irrigation is a large part of its summer load, and this coincided in time with the delivery of power from the plant of the Irrigation District. Thus, a net revenue was made possible for the Irrigation District sufficient to pay the fixed charges on the cost of reservoir and power plant, amounting to more than $7 000 000.

In the development of hydro-electric power systems of the Pacific Coast States many changes have been brought about. These changes are the joint product of the civil, mechanical, and electrical engineers. As a rule, most of the expenditure comes under the control of the civil engineer, but the engineer in charge of any system must have a fair knowledge of all the problems involved. The speaker must express a high degree of appreciation of the mechanical engineers who have perfected the modern American impulse wheels and turbines and of the electrical engineers who have designed and built the high efficiency and mechanically perfect generators, transformers, switches, and other parts that are a part of the complicated power plant.

HIGH-VOLTAGE PHENOMENA ENCOUNTERED IN POWER TRANSMISSION

By Harris J. Ryan,* Esq.

Electrical power transmission fundamentally involves the care of the following:

I.—A proper cross-section of conductor to accommodate the requisite current.

II.—An adequate non-conducting support and submerging medium for the transmission conductors, that will withstand the application of the necessary high voltage without appreciable leakage of current, that is, an adequate system of insulation.

III.—The stability of voltage values.

The provision of a conductor of proper cross-section is an economic consideration and gives rise to few practical or technical difficulties. Under the usual schedule of costs, the most economic section of copper conductor per ampere, is never much more than that of a No. 18 B. & S. gauge wire. Such a conductor weighs 26 lb. per mile and has a resistance of about 35 ohms per mile. It follows, therefore, that the weight of the copper conductor is about 26 lb. per ampere per mile, and the corresponding voltage required to supply the power lost in such a conductor is 35. This value of 35 volts that must be lost economically in a copper transmission line, is fundamental. Electrical power conductor-transmission efficiency, therefore, can never vary greatly from

$$\varepsilon = \frac{35\,D}{E_0}$$

wherein E_0 is the voltage to ground or to "neutral", used for transmission, and D is the distance, in miles.

The total economic cost of power transmission due to the conductor alone is the sum of the existence cost attached to the conductor section and the cost of the conductor electrical loss. The fundamental relation of transmission voltage, distance, and conductor-transmission cost, is: Total conductor transmission costs vary directly as the transmission distance and inversely as the voltage.

Whenever practicable, the relation of transmission-line voltage to transmission distance is about 1 000 volts per mile in a three-phase circuit (575 volts from conductor to neutral). This results in a power loss of $100 \times \frac{35}{575}$, or 6.1%, and a total conductor-transmission cost, therefore, of 12.2 per cent. Under this allowance of working voltage, water power has been developed during recent years in intermediate amounts for single projects of 100 000 to 200 000 kw. and transmitted to profitable markets over correspondingly intermediate distances of 100 to 250 miles, using voltages from 66 000 to 165 000.

The economic conditions on the Pacific Coast and in other sections of the United States now demand the development and use of all outstanding water

* Prof. of Elec. Eng., Leland Stanford Junior Univ., Stanford University, Calif.

powers and the transmission of power to profitable markets. Individual projects involve the development of blocks of power varying from 250 000 to 1 000 000 kw., or more, to be transmitted for the greater part, over distances from 250 to 500 miles or more.

When active preparations for the first of these large modern projects were begun in 1919, it was realized that voltages higher than those in use at that time would have to be employed to insure economic and practical success. The technical difficulties involved would have to be solved, and the whole subject of power transmission would have to be studied with respect to the available technical expediencies and practical options of every kind, in order that the next advance in voltage might be made advisedly for the general mobilization of all economic sources of power. During the past three years, much work has been done by power-transmission engineers co-operating for the interests they represented, and by committees of the National Electric Light Association and the American Institute of Electrical Engineers. The result of this effort has been the virtual adoption by common consent of 220 000 volts and the development of dependable line insulators, transformers, and switch-gear required for the application of such voltage.

Many arguments for and against the adoption of 220 000 volts have been considered. The majority of these arguments, although often the cause of much controversy, are of little importance. There are three inter-related factors, or groups of factors, to which the final decision is largely due, as follows:

I.—Economy in transmission, as such, demands the highest available working voltage.

II.—High voltages are extravagant of space, demanding liberal air-space clearances adjacent to all insulator supports of 18 000 volts per ft., for example, 7 ft. at a minimum for the use of 127 000 volts to ground occurring in a 220 000-volt transmission.

III.—For the transmission of a given amount of power, the idle re-active power required to maintain the electric field attached to the transmission circuit is positive and increases directly as the square of the transmission voltage; the corresponding magnetic field is negative and increases inversely as the square of the transmission voltage.

The nature of Factor I will be understood when it is recalled that power costing 0.2 cent per kw-hr. at the large power plant will cost approximately an equal amount to transmit it 300 miles, using 220 000 volts, to a profitable market. The corresponding conductor part of this cost is $\frac{2 \times 100\ (35 \times 300)}{127\ 000}$ = 19.3 per cent. Elevating the voltage, therefore, can effect a reduction only in a one-fifth part of the transmission cost and must simultaneously encounter increased costs on account of Factor II and greatly increased costs on account of Factor III.

Factor II is the effect on the cost of transmission, due to a necessary linear increase of clearances in air, oil, and solid insulations, with a corresponding increase of line voltage. Tower structures, transformers, and switch-gear are

to be had, therefore, at fair unit costs only when the magnitude of power transmitted is sufficiently great per circuit (100 000 to 200 000 kw.), otherwise the saving in conductor-transmission cost is rendered of no value by the accompanying increased cost of auxiliary equipments.

Factor III affects plant capacity (that is, the power factor) and voltage control. When capacitance and inductance are connected in series in the electric circuit, they consume correspondingly positive and negative re-active powers by the production of opposing voltages that are in lagging or leading quadrature with the electric current. If the re-active powers thus consumed are equal, the corresponding voltages produced are equal and opposite. Their resultant is zero. The conductor-transmission power factor remains unity. When such inductances and capacitances are connected in parallel with the electric circuit, opposing currents instead of voltages are set up. If the re-active powers thus consumed are equal, the sum of their corresponding currents is zero. The net result is substantially the same as in the preceding case. If, however, inductance is connected in series with the circuit and the capacitance in parallel, as is the case in the long transmission circuit, the inductive or magnetic and the capacitive or electric re-active powers are consumed by setting up corresponding voltage and current. They are unlike components of re-active power and cannot be added directly without the one being first transformed to the form of the other.

The most practical transformer for this purpose is the so-called synchronous condenser. It should more properly be called the re-active alternator as it may be made at will to accept quadrature leading or lagging current from the transmission line at any point by a proper adjustment of field excitation. In the discussion that follows, it is assumed that re-active alternators of suitable negative kilo-volt-ampere capacity are connected across the transmission line at intervals of about 150 miles, as requisite facility for mixing en route through the transmission line the opposing electric and magnetic re-active powers consumed by the line, so as to have to transmit in the aggregate only the resulting re-active power residual and to maintain a constant line voltage and power factor, as proposed recently by F. G. Baum, M. Am. Soc. C. E.*

A 100-mile, 110 000-volt, three-phase, 60-cycle, 32 200-kw., power-transmission circuit requires equal and opposite re-active powers (6 700 kv-a. each) to maintain the electric and magnetic fields attached to such a circuit. This circuit, therefore, will have a conductor-transmission power factor of unity. For these power-transmission values, Factor III is the cause of no difficulty. Unfortunately, when the power is transmitted in a fixed amount, the re-active power required for the electric field increases directly as the square of the transmission voltage and for the magnetic field, inversely as the square of such voltage, and each increases directly as the transmission distance. Thus, on increasing the voltage from 110 000 in the case cited, the excess of re-active power required for the maintenance of the electric field over that in opposition required for the corresponding magnetic field, increases with great rapidity, causing a corresponding reduction in power factor and voltage

* "Voltage Regulation and Insulation for Large Power, Long-Distance Transmission Systems", *Transactions*, A. I. E. E., Vol. XL (1921), p. 1017.

stability. Only by increasing the power transmitted per circuit can this excess of electric re-active power be limited satisfactorily.

Taking the values in the case cited as units for a comparison of the electric and magnetic re-active powers required for other values of line voltage, E, the line voltage, will occur in 110 000-volt units, the distance, D, in 100-mile units, and the power, P, in 32 200-kw. units, the values of the opposing re-active powers required to maintain the fields attached to the transmission circuit, are:

$$\text{Electric re-active power} = (+)\ \overline{K\,V\,A}_e = 6\,700\ .\ D\,\overline{E}^2 \quad \text{(1)}$$

$$\text{Magnetic re-active power} = (-)\ \overline{K\,V\,A}_m = 6\,700\ .\ \frac{D\,\overline{P}^2}{E^2} \quad \text{(2)}$$

By equating these values of the electric and magnetic re-active powers, the corresponding relation of the values of power and voltage in the units adopted is found to be:

$$P = E^2 \quad \text{(3)}$$

It follows that the power per circuit must increase as the square of the voltage, in order to transmit at a full-load, conductor-power factor of unity. Three of these corresponding voltages and powers are, as follows:

Three-phase line voltage, in kilovolts.	Power transmitted per three-phase circuit, required for a conductor-power factor of unity, in kilowatts.
220	128 000
330	298 000
440	512 000

It is seen, therefore, that as the voltage is raised above 220 000, the magnitude of power per circuit required for a conductor-transmission power factor of unity quickly becomes excessive. It follows, therefore, that 60-cycle, alternating, transmission voltages cannot be used at values of much more than 220 000 without a serious loss of the power factor and a corresponding increase of the non-productive capacity of the synchronous machinery required to maintain the high electric fields that inevitably attach to circuits at high voltage.

The curves in Fig. 23 have been determined to show the approximate relations between magnitudes of 60-cycle power transmitted per circuit, residual re-active powers, and line voltages, for distances of 250 and 500 miles.

If the frequency was lowered from 60 to 25 cycles, each of the opposing re-active powers would be reduced to about 40% of their former values, permitting a corresponding increase in transmission voltage from 220 000 to 350 000. The saving in conductor economy thus effected would be offset so largely by increased costs of transformers, switches, and the greater clearances required for insulation, that the gain would be uncertain. By common consent, therefore, no reduction in frequency has been proposed for the large power projects and for the nation-wide power network.

The curves, Fig. 23, show likewise that a transmission voltage of 220 000 would be unduly high for the satisfactory transmission of power magnitudes much less than 100 000 kw. per circuit, again, because of the relatively exces-

sive values of re-active power required to charge the electric fields surrounding the conductors.

The conclusion is reached, therefore, that the best transmission voltage for the establishment of the general power network is 220 000 at 60 cycles. With such a voltage, power can be transmitted with practical satisfaction over distances from 200 to 500 miles or more.

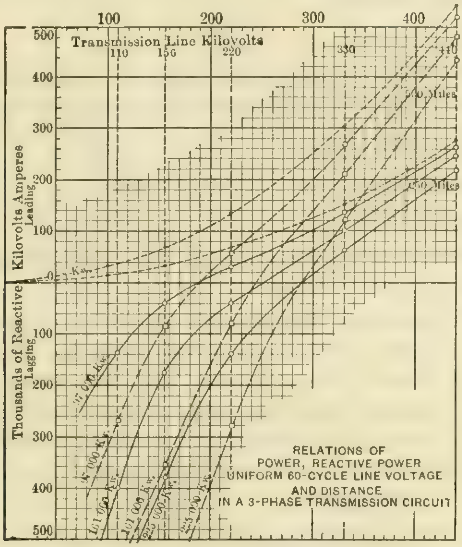

FIG. 23.

An open mind should be maintained toward the possible availability in the future, of high continuous voltages of 500 000 or more. Responsible manufacturers are engaged on the solution of this problem. They propose to use continuous high-voltage currents by rectifying alternating, three-phase, high-voltage currents at their source and resolving them into low voltage, three-phase, alternating currents for distribution at their markets, with electron valves for each transformation. It does not appear likely that such continuous high-voltage currents will ever replace alternating high-voltage currents in the general power network. It does appear quite possible, however, that, in the future, they may be used for trunk-line connections between the large centers of power and the markets that have been consolidated by the general network.

The foregoing are the more important of the useful high-voltage actions found in the electrical power industry. There are also the non-useful or predaceous high-voltage phenomena that occur in power-transmission circuits due to accidental causes. The causes of most predatory high-voltage phenomena are:

Over-voltages from within the transmission circuit, due to:

1.—Switching.

2.—Breaking short circuits.

3.—Arcs between circuit terminals and from some point in the circuit to the ground.

4.—Engine or turbine-generator runaways.

5.—Resonance.

Over-voltages from without the circuit, due to:

6.—Lightning, rarely from direct stroke, generally through the release of bound charges.

Corona formation, due to:

7.—Use of conductors that are too small to prevent over-stresses in the adjacent atmosphere, permitting an escape of power.

Conductor supports through:

8.—Depreciation and failure of line insulators.

Space factors causing:

9.—Flash-overs from conductors to towers, cross-arms or ground cables not due to over-voltages:

(*a*). Accounted for through tangible evidences, for example, such flash-overs may be caused by the surfaces of insulators being covered with salt-laden dust and, later, wetted with fog, mist, or rain, a circumstance that is likely to develop an accounted-for flash-over.

(*b*). Unaccounted-for, infrequent, and now under searching investigation.

Most of these enemy phenomena have been studied successfully, and their characters and the elimination of the troubles they cause are now thoroughly understood. Suppression of corona losses by conductors of proper dimensions, the nearly total suppression of flash-overs and short circuits by the proper construction of insulator and other conductor supports, and the high insulator durability have been accomplished. The causes of failure of transmission lines due to flash-over and other predatory phenomena listed, generally occur singly, both as to time and location. The power-service interruptions which they produce, have been reduced to a working minimum by means of double transmission lines and switching stations located at intervals of 25 to 50 miles and equipped with automatic switches that isolate the line section in trouble, and by care in construction, operation, and maintenance.

In regard to predatory high-voltage phenomena occurring in power transmission, much the same rule applies as in other lines of service, namely, eventually everything that can happen, will happen. For this reason, engineers responsible for the reliability of power service are devoting much study nowadays to every known form of electricity in action at high voltage, in order to establish a foundation on which to erect an understanding of the cause and prevention of all electrical accidents or failures that occur in power-transmission practice.

GROWTH OF THE USE OF ELECTRIC POWER IN SOUTHERN CALIFORNIA AND PROBABILITIES OF ITS FUTURE GROWTH WITH REFERENCE TO SOURCES OF HYDRAULIC POWER

By Harry W. Dennis,* M. Am. Soc. C. E., and H. A. Barre,† Esq.

Southern California is supplied with electric power by five companies, namely, the Southern California Edison Company, the Southern Sierras Power Company, City of Los Angeles, the Los Angeles Gas and Electric Corporation, and the San Diego Consolidated Gas and Electric Company. The last two companies depend on steam for primary power. The Edison Company serves a territory equal to the entire area of the States of Vermont, New Hampshire, Connecticut, Rhode Island, New Jersey, and Delaware, supplies 65% of the power used in Southern California, and must be depended on for 90% of the hydro-electric power yet to be developed inside the State for the use of Southern California. Therefore, a description of the growth of the Southern California Edison Company and the use to which its power is put, together with deductions from its extensive plans for future development, will be typical of Southern California.

It is interesting to note that, during the period from 1900 to 1920, the population represented by the ten counties served by the Edison Company has increased more than 300 per cent. Parallel with this phenomenal growth, the Edison Company has increased its generating capacity from 12 000 h.p., in 1900, to 380 000 h.p., in 1921. It has increased the number of kilowatt-hours generated from 379 900 000 in 1910 to 1 079 000 000 in 1921. The number of consumers during the same period has increased from 5 000 to 276 000. The details are given in Tables 11 to 15, inclusive.

TABLE 11.—Growth of Electric Power Production in Southern California, as Represented by the Southern California Edison Company.

Year.	Millions of Kilowatt-Hours Produced by:			Percentage, annual kilowatt-hour growth.
	Water power.	Steam and purchased power.	Total.	
1910	253.8	126.1	379.9	14.5
1911	279.3	162.9	442.2	16.2
1912	250.3	272.9	523.2	18.2
1913	281.5	309.3	590.8	13.0
1914	518.3	117.0	635.3	7.5
1915	555.9	103.7	659.6	4.0
1916	639.1	61.1	700.2	6.0
1917	608.6	151.7	746.8	6.2
1918	608.6	204.5	813.1	8.7
1919	564.9	361.2	926.1	14.0
1920	627.5	350.2	977.7	5.0
1921	832.6	246.5	1079.1	10.4

* Constr. Engr., Southern California Edison Co., Los Angeles, Calif.

† Executive Engr., Southern California Edison Co., Los Angeles, Calif.

TABLE 12.—USES TO WHICH ELECTRICAL ENERGY IS BEING APPLIED AND THEIR GROWTH DURING THE PERIOD 1910 TO 1921.

Figures Given in Millions of Kilowatt-Hours.

Year.	Total sold.	Lighting.	Agriculture.	Railroads.	Cement mills.	Industrial.
1910	327	37.3	73.3	189.7	......	27.7
1911	363.8	44.1	72.0	207.6	8.9	31.2
1912	431.5	50.9	90.5	217.4	37.2	35.5
1913	490.9	59.1	111.0	236.7	42.8	41.3
1914	494.9	68.2	102.0	239.2	37.7	47.8
1915	513.7	74.4	107.0	248.6	30.4	53.3
1916	536.9	88.5	110.0	247.8	29.6	61.0
1917	631.5	86.9	129.0	262.3	36.9	116.4
1918	685.9	83.5	150.0	268.5	31.7	152.2
1919	759.6	94.9	162.0	252.3	28.0	222.4
1920	844.5	117.8	168.0	277.5	54.7	226.5
1921	917.7	137.6	176.6	271.4	54.4	277.7

TABLE 13.—GROWTH OF GENERATING STATION CAPACITY. THIS INCLUDED ALL THE SYSTEMS NOW CONSTITUTING THE SOUTHERN CALIFORNIA EDISON COMPANY.

Year.	NUMBER OF PLANTS ADDED:		Horse-power.
	Water power.	Steam power.	
1893–1900	5	1	12 000
1901–1906	7	3	41 600
1906–1907	1	1	34 400
1908–1910	1	1	55 000
1911–1914	2	1	149 000
1915–1917	1	......	2 700
1918–1921	2	......	94 500

TABLE 14.—BIG CREEK POWER PROJECT POWER PLANTS, ULTIMATE DEVELOPMENTS.

	Static head, in feet.	Installed horse-power.
Power House No. 1..............	2 130	86 000
Power House No. 2..............	1 860 and 2 400	387 000
Power House No. 3..............	855	200 000
Power House No. 4	340	67 000
Power House No. 5..............	1 480	134 000
Power House No. 6..............	1 650	147 000
Power House No. 7..............	1 900	40 000
Power House No. 8..............	729	180 000

NOTE.—There is now installed 43 000 h.p. at Power House No. 1; 65 000 h.p. at Power House No. 2; and 30 000 h.p. at Power House No. 8.

The five major uses to which this electrical energy is being applied are lighting, agriculture, railroads, cement mills, and manufacturing. The lighting use consists of municipal as well as private arc and incandescent lighting; the agricultural use consists chiefly of pumping for irrigation purposes; the railroads use more than 271 000 000 kw-hr. to operate the local city lines and interurban system, extending in all directions from Los Angeles; three cement mills account for a large amount of used power each year; and the manufacturing use includes more than eighty industries.

TABLE 15.—BIG CREEK POWER PROJECT STORAGE RESERVOIRS, ULTIMATE DEVELOPMENT.

Name of reservoir.	Capacity, in acre-feet.	Total head, in feet, through which water may be used.
Vermilion Valley	90 000	5 914
Florence Lake	40 000	5 914
Blaney Meadows	15 000	5 914
Huntington Lake	88 000	5 914
Shaver Lake	146 000	4 324
Granite Creek	22 000	5 474
Jackass Creek	27 000	5 474
Chiquito Creek	18 000	3 574
Mammoth Pool	28 000	1 924
Total	474 000	....

The relative magnitude of the different classes of business may be shown from the connected load for each class. The total connected load of the Edison Company is 800 000 h.p., and is subdivided as follows:

Lighting	280 000 h.p.
Agriculture	160 000 h.p.
Railroads	105 000 h.p.
Cement mills	25 000 h.p.
Manufacturing	230 000 h.p.

On account of the diversity in its use, this total connected load of 800 000 h.p. is served by a maximum simultaneous plant output of only 320 000 h.p. This diversity results from the alternating requirements of agriculture, industrial and domestic service, and the extent of the territory served.

Agriculture is bound to expand, and although the Edison Company supplies the power for irrigating 550 000 acres of land, there yet remain in the territory served more than 1 000 000 acres capable of being irrigated by pumped water. The 300 kw-hr. used yearly in irrigating an acre of arid land, raises the sale value of the land from $30 to $225 and yields an annual return of $50 to $100 in crops. Consideration of this fact leads to the conclusion that the use of electric power for irrigation requirements will expand until every available acre for which there is water will be brought into cultivation.

Modern conditions demand electric service for farm, home, and factory. Domestic consumption, which depends on population, will increase rapidly as long as new appliances continue to make power more and more a necessity in the home. Certain railroads in Southern California will be electrified when the increasing consumption of fuel oil again overtakes the supply.

Electricity is, therefore, the motive power on which the industries of California depend—agriculture, manufacturing, and transportation cannot go forward without an adequate supply of electric power. The demand for power increases in proportion to the growth and expansion of these industries.

Based on past performances in the growth of electric power production (Table 11), it appears that the rate has been an annually compounded increase of approximately 10 per cent. With a continuation of this rate of growth,

estimates of the load have been prepared, which indicate a total load in 1935 of more than 1 000 000 h.p. An additional capacity of about 50 000 h.p. per year is now required.

The water power plants of the San Antonio Light and Power Company, on the San Antonio Creek, the Redlands Light and Power Company, on Mill Creek and the Santa Ana River, and the steam plant of the West Side Lighting Company, of Los Angeles, represent the beginning of the composite system now known as the Southern California Edison Company. These early plants, operating in the Nineties, were among the first in the generation of so-called high-tension transmission of power, not only in Southern California, but in the United States.

This harnessing of the small foot-hill streams comparatively close to Los Angeles, utilizing the water as it came, without storage, was the source, in the early days, of a power supply. As the load demands became larger, it was necessary to go farther away for the power until, in 1913, the initial installation of the well known Big Creek project was completed.

In order to meet the future demand, a comprehensive survey has been made of the potential power available and a construction program adopted covering the development of more than 1 260 000 h.p., 1 120 000 h.p. of which is on the San Joaquin River, 80 000 h.p. on the Kern River, and 21 000 h.p. on the Kaweah River. This program is expected to take care of the needs of the service for the next few years, and will be put into effect not only in the most economical way, but also in the order and in the necessary amounts which best supply the load demand.

This plan of construction is already in effect on the San Joaquin River and its tributary, Big Creek. The initial units were built on Big Creek, about 70 miles east of Fresno, Calif. These plants consisted of Huntington Lake Reservoir, with a storage capacity of 88 000 acre-ft., at an elevation of approximately 7 000 ft., supplying, successively, Big Creek Power Houses Nos. 1 and 2, each with an installed capacity of 43 000 h.p., operating under static heads of 2 130 ft. and 1 860 ft., respectively. The current was transmitted to Los Angeles, a distance of 241 miles, at 150 000 volts, over two, single-circuit, transmission lines, terminating in the large substation of Eagle Rock, near Los Angeles.

These power-houses and transmission lines were placed in operation in 1913, and represented an investment of about $16 500 000. This initial installation of 86 000 h.p. in itself was a large undertaking, but was only the beginning of the ultimate development of the San Joaquin River, which will be 1 250 000 h.p.

The general plan for developing this great source of hydro-electric power consists of the construction of a chain of power-houses in series between Huntington Lake, with an elevation of 7 000 ft., and the tail-water of Big Creek Power House No. 4, with an elevation of 1 000 ft. This chain of power-houses, in the order of their location, beginning at Huntington Lake, will consist of Power Houses Nos. 1, 2, 8, 3, and 4. Water from Huntington Lake may also be conducted to a proposed second storage reservoir known as Shaver

Lake, of 146 000 acre-ft. capacity, and in its passage between the two reservoirs, will go through Power House No. 5. From Shaver Lake, the water will pass through Power Houses Nos. 2, 8, 3, and 4.

In addition to these power houses using the stored waters of Huntington and Shaver Lakes, two other power sites, not using these stored waters, will be developed. One of these, known as Power House No. 7, located on the middle fork of the San Joaquin River, offers an ultimate development of 40 000 h.p., under a head of 1 900 ft. The other, known as Power House No. 6, located on the main San Joaquin River above its junction with Big Creek, is capable of a development of 147 000 h.p., at a head of 1 650 ft. The principal hydraulic features of the project are shown on Fig. 24.

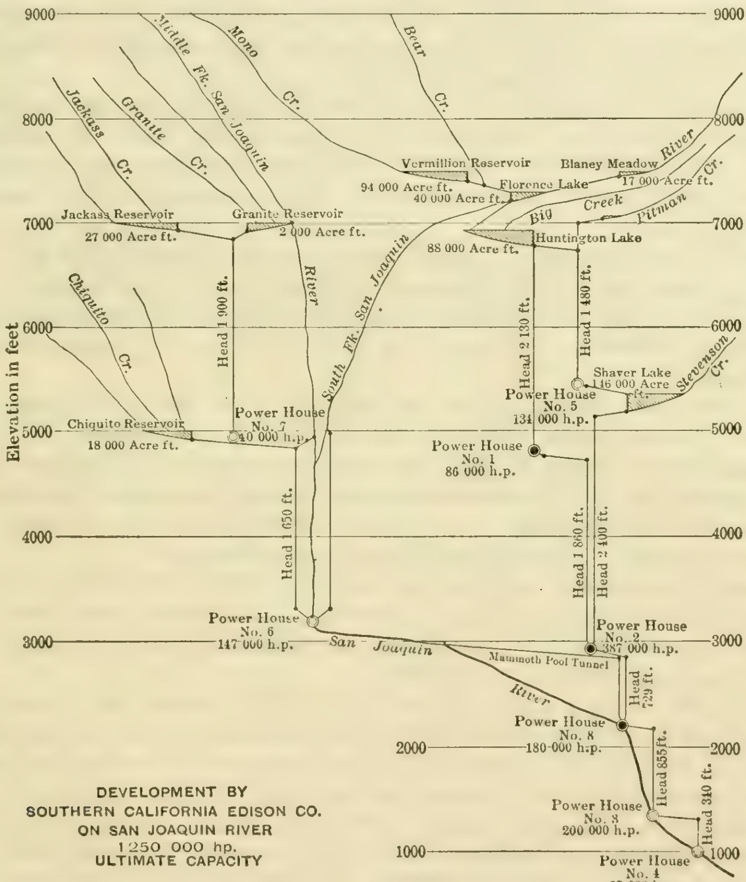

FIG. 24.

Huntington Lake is now supplied exclusively from Big Creek, with a drainage area of 79 sq. miles. In order to increase the water supply to Huntington Lake, the development program includes the construction of Florence Lake Tunnel, 13.5 miles in length, of a capacity of 1 000 sec-ft., which will

tap the Upper San Joaquin at Florence Lake and is expected to be completed by April, 1926. Through this tunnel, the waters of the south fork of the San Joaquin River, together with Mono and Bear Creeks, will be diverted into Huntington Lake. Later, reservoir capacity up to 146 000 acre-ft. will be provided at Shaver Lake. A tunnel connecting Huntington Lake with Shaver Lake will be built, so that the combined capacities of those lakes can be used in storing the excess waters delivered through Florence Lake Tunnel. Complete utilization of this water will produce 750 000 000 kw-hr. per year, representing a value of more than $11 000 000 annually.

Following its proposed construction program, the Edison Company has completed the first 30 000-h.p. unit in Power House No. 8; added a third unit of 21 500 h.p. to Power House No. 2; raised the dam at Huntington Lake, and enlarged the capacity of the Eagle Rock Sub-Station. The investment in the San Joaquin River development has now increased $22 835 000, with an installation of 137 500 h.p.

Work is now in progress on Power House No. 3, which will have an initial capacity of 100 000 h.p. This plant will be completed in 1923. In addition, a third unit of 21 500 h.p. will be installed in Power House No. 1, and the voltage on the Big Creek transmission line will be increased to 220 000, thereby doubling its capacity.

The Edison Company will expend more than $27 000 000 during 1922 for new water-power plant construction and additional distribution facilities. Its plans call for the addition of 322 000 h.p. during the next 6 years, which will require an expenditure of more than $125 000 000 for its production and distribution.

In addition to the program of development of the Edison Company, the Southern Sierras Power Company and the City of Los Angeles also have developed water powers and plans for future water-power construction. The Los Angeles Gas and Electric Corporation and the San Diego Consolidated Gas and Electric Company, except for some small water-power projects, rely on steam-generated power for both present and future needs.

Among these central stations, the most important possibilities are those of the City of Los Angeles along its aqueduct. The ultimate capacity of the aqueduct plants is given as 250 000 h.p., of which 97 300 h.p. will have been placed in operation by the end of 1923.

As all the present plants of the City of Los Angeles are situated at hydraulic drops along the aqueduct, they utilize conduits which would be built for Water Department purposes even if no power was to be produced, and the minimum of hydraulic construction has been necessary. This fact, and the short distance of transmission, has resulted in the cheapest power that ever can be expected in Southern California, a condition from which the City of Los Angeles derives the full benefit. The City authorities have filed also on sites on King and Kern Rivers for a large amount of power, concerning which no published information is available.

As to future plants, it should be noted, both in connection with the Los Angeles Aqueduct and King and Kern Rivers, that the cost must include the full amount of the hydraulic construction and long-distance transmission.

The total power possibilities of the Southern Sierras Power Company aggregate about 175 000 h.p., of which approximately 75 000 h.p. is in operation delivering power in Nevada, Owens River Valley, Riverside, and San Bernardino Counties, and the Imperial Valley.

There remains as the future power supply for Southern California and, by releasing the San Joaquin power to the northern part of the State, for the whole of California, a pro rata part of the 4 500 000 h.p. on the Colorado River. Although much discussion has been given to this topic, there has not been time nor the necessity to make the careful investigation needed to prepare an adequate plan for utilizing the resources of the Colorado. There is a great temptation to start such a project on a scale that the available market cannot immediately support. What should possibly be looked for first is not how large a development can be made, but with how small a development can a start be made. Knowledge of this stream should be increased during the next few years, and the inception of a practicable plan devised for its initial and ultimate utilization, not on the basis of benefit to any one organization or interest, but in a manner whereby the public interest as a whole can most adequately be served.

The power industry has fully met the demands for electrical energy in Southern California from the beginning of commercial generation and transmission. The present companies in this field have definite, comprehensive plans to meet the increasing demand for a few years, and, at the appropriate time, must be prepared to undertake the development of the Colorado River for general service to the entire Southwest.

HYDRO-ELECTRIC POWER DEVELOPMENT AS RELATED TO THE ELECTRIFICATION OF RAILROADS

By C. F. Loweth,* M. Am. Soc. C. E.

The title of this paper may lead to the assumption that cheap and abundant hydro-electric power in itself would justify the electrification of steam railroads. In the writer's opinion, such an assumption would be incorrect. The electrification of steam railroads, thus far, at least in the United States, has come about more largely from causes other than cheapness of electric power. The necessity of avoiding smoke and steam in tunnels and other restricted places, and the need of increasing the capacity of tracks or other terminal facilities have generally been the determining factors which have brought about electrification. However, it is not improbable that conditions in this respect may change; doubtless, increase in volume of railway traffic and the known economies of electrification will tend to increase the use of electricity for the operation of railroads in localities where cheap and reliable hydro-electric power is available.

Something more than a mere showing of economy will be necessary to bring about a change from steam to electric operation of railroads. Electrification will involve a large increase of invested capital, and, at the same time, the retirement of many facilities which would not be needed with a change of power. Under the many adverse conditions with which the railroads in this country have contended in the past few years, their financial credit has been impaired; only a few of them have a surplus of earnings available for improvements, and the additional capital necessary therefor cannot be readily and cheaply obtained. Under the accounting rules of the Interstate Commerce Commission, the cost of facilities which are retired must be charged to profit and loss; such charges would be quite large, would be undesirable, and would have much the same effect as if they were charged to operating expenses.

The admitted economies of electrification have to contend with a constantly increasing efficiency of steam locomotives. Much study has been given to steam locomotive design with a view to greater efficiency; superheaters, stokers, better water, and many other appliances have made the modern steam locomotive a much more efficient and reliable prime mover than is generally supposed. This, together with the revision of gradients, additional and better facilities, and improved methods of operation, tend constantly to reduce the margin of economy which would justify electrification.

Electrification has some outstanding advantages which probably never can be equalled by steam operation. Some of these advantages are the longer continuous operating periods possible with electric locomotives, their greater power in single units, with less destructive effect on rolling stock and track than steam locomotives, the elimination of coal and water facilities, and the reduction in the number of engine terminals and the delays occasioned thereby.

* Chf. Engr., C. M. & St. P. Ry., Chicago, Ill.

It is evident that these and all other advantages arising from electrification will vary with each particular railroad and for different points on the same railroad, and must be weighed as against all the factors affecting the cost of steam operation, of reducing gradients, and of increasing track and other facilities so as to cheapen present steam operation, and, lastly, the increased investment cost of electrification, including the retirement charges of facilities that would be retired. It is evident, therefore, that the cost of electric power is only one of many factors entering into the problem, but the more reliably and cheaply electric power becomes available, to that extent will it prove a favorable factor in electrification. To the extent that hydro-electric power is more readily available, more reliable, and cheaper than steam-generated power, to the same extent, approximately, will it be a more important factor. Even so, at this time it does not appear probable that the change from steam to electric operation would be justified for existing railroads, except where the volume of traffic is large, where it can be moved in large units for long distances, where fuel costs are high, and where operating costs due to adverse gradients and congestion of track and other facilities make steam operation somewhat more than ordinarily expensive.

Wherever the determining factor for the electrification of steam railroads has been the need of avoiding smoke in tunnels or densely populated terminals, or of increasing the capacity of tracks or other facilities, the insistence of the demand for the change has been so great, as a rule, that the cost of power has been only a minor factor. Generally, such cases have involved only restricted areas and have left much larger areas to continue to be operated by steam. The economies of electric operation in such cases probably would be increased materially by largely increasing the mileage of road electrically operated. The greater the extent of electrically operated mileage, the more important factor will become the cheapness of electric power.

Coal and fuel oil costs vary from time to time; in the last few years, the fluctuations have been extreme and, what is even more important and, at the same time, an indictment of American business and industrial methods, is the fact that fuel supplies have sometimes been uncertain. On the contrary, it would appear that, once the installation has been made, hydro-electric power would fluctuate as to supply within well defined limits, and that the cost, or at least the selling price, would be constant, or nearly so, for long periods. The ability to contract for an ample and reliable supply of hydro-electric power at favorable prices extending over a long term might easily prove a controlling factor in the electrification of railroads, especially for new railroads where the cost of coal, water, and engine terminal, as well as other facilities incident to steam operation, would be eliminated.

To illustrate this problem better, reference will be made to the electrification of sections of the Chicago, Milwaukee and St. Paul Railway, which is probably one of the largest electrification projects with respect to main-line mileage. Electrification was considered coincidently with the location and construction, in 1906-08, of the extension of this Railway System from Central South Dakota to the Pacific Coast, a distance of about 1 400 miles. The extension crossed several mountain ranges where long and heavy gradients

were necessary. Undeveloped water powers were abundant and power requirements for industrial uses were largely absent. These conditions led early to the suggestion that parts of the extension should be electrified; accordingly, the Railway Company acquired several water-power rights, and, at some places, located its lines with reference to the development of these powers. However, electrification was delayed, and on the completion of the railroad, it was operated by steam. It was not until several years later, about 1914, that the electrification of the section between Harlowton and Deer Lodge, Mont.—228 miles—was begun, and previous to the completion of this section, work was begun on the adjoining section from Deer Lodge to Avery, Idaho, making a total of 440 miles of main line. These sections crossed the main Continental Divide and the Belt and Bitter Root Mountain Ranges. Recently, the 209-mile section between Othello, in Central Washington, and Seattle and Tacoma, was electrified. A gap of main line between Avery and Othello (226 miles) is left, which undoubtedly would have been electrified before now, except for the abnormal conditions brought about by the World War and Federal control.

For various reasons, the Railway Company found it undesirable to add to and develop its own power requirements; therefore, it disposed of the power sites and made long-term contracts for power. The powers of which the Railway Company had obtained control were small compared with those now depended on, and the cost of their development would have been relatively much higher. They would have been subject to wide seasonal fluctuation as to quantity, and there would not have been the same high degree of reliability of power supply that exists under the present arrangement. The net cost of power to the Railway Company would also have been greater; at times, it would have been obliged to purchase power, and, at other times, it would have had surplus power to sell. The power now used and that already under contract for the 226 mile gap between Avery and Othello will be hydro-electric power. The contracts for power are with the Montana Power Company, the Inter-mountain Power Company, the Washington Water Power Company, and the Puget Sound Light and Power Company, the first named company supplying the greater part. All these companies control large supplies of developed as well as of undeveloped water power. The contracts for this power run for long periods. The first contracts were for 99-year terms, and the later contracts will expire practically concurrently with those first made. The cost of the current delivered at the Railway Company's sub-stations is the same for all contracts, and at a very low price. The several power contracts are inter-related with agreements between the several power companies which, in effect, is practically equivalent to one contract covering all the railway's requirements for the electrified section. The Railway Company is, therefore, depending not on the individual power resources of these several companies, but on their combined resources, as the generating stations of the companies are so many and so completely tied together as to insure an uninterrupted supply for the entire electrified section. The eighteen or twenty generating stations supplying power under these contracts extend over a territory from Central Montana to Puget Sound, a distance of more than 650 miles,

with a north and south width of nearly 200 miles. The drainage areas supplying these powers not only cover a much larger territory, but they also differ greatly as to climatic and topographic conditions, a factor which it is believed insures a reliability of power supply under the most extreme conditions. The combined capacity of these stations is more than 360 000 kw. Within this area, and adjacent to it, are many undeveloped water powers. There can be no question but that this combination of ample, reliable, and cheap power, supplied under long-term contracts, at a low price, is an important factor in justifying this extensive railway electrification.

The other factors justifying the electrification were the remoteness from fuel supplies, the long stretches of steep gradients, the character of freight traffic, which permitted it to be concentrated in large train units, the considerable mileage of railway electrified, and, last, but not least, the fact that the railway company would be able to control the flow of traffic over the electrified sections in such manner as largely to eliminate extreme peak loadings. All these last named considerations, of course, would apply more or less equally to an electrification using steam-generated current.

In this connection, it is interesting to note that this railway prior to electrification used oil for locomotive-fuel purposes exclusively for the main line and for the branches from Deer Lodge to the Pacific Coast, the oil being shipped by water from the Southern California fields. At that time and for a period of several years, oil was cheaper for the railway than coal, and had the further advantage of minimizing fire risks, an important consideration because the line crosses several forest reservations. Later, for those sections of the railway that were not electrified, it was necessary to change from fuel oil to coal.

Of the various electrifications of steam railroads in the United States, the majority are using steam-generated current. The several electrifications centering in and about New York City, the Pennsylvania Railway, at Philadelphia, Pa., and its West Jersey and Sea Shore Railway, the Norfolk and Western Railway, the Detroit, Sarnia, Hoosac, and Baltimore Tunnels are all operated by steam-generated current. Both steam-generated and hydro-electric currents are used for the Canadian National Railway Tunnel at Montreal, Que., Canada, mostly the latter, whereas for the Great Northern Railway Tunnel in Washington only hydro-electric current is used. The Butte, Anaconda and Pacific Railway (which carries a heavy freight traffic) and the Spokane and Inland Empire Railroad lines use hydro-electric power exclusively, the former being supplied by the Montana Power Company.

The abundance and cheapness of hydro-electric power, especially as compared with steam-generated power, have probably been more the controlling factors in the electrification of steam railroads in foreign countries than in the United States. This is shown in the official reports made to the International Railway Congress held in Rome, Italy, in the early part of 1922. As to Sweden and Norway, Mr. Ofverholm, Chief of the Electrical Department of the Swedish State Railways, and Official Reporter to the Congress, states:

"Sweden, Norway, and Denmark have not the necessary quantity of home-produced coal. The coal fields that exist in the south of Sweden are quite inadequate, and the coal is of poor quality. On the other hand, Sweden and Norway have plenty of water power, though this is not the case with Denmark. In the first two countries, railway electrification on a large scale has been contemplated, in order to utilize water power instead of depending on imported coal. In Denmark, owing to the lack of water power, no such schemes are in existence.

"The desire to make the railways independent of foreign coal has been entertained in Sweden for a long time."

Later in the report, where the program for electrification is being considered, he states:

"The chief point is to make the railways independent of foreign coal; therefore, the lines that have the highest coal consumption should be the first to be electrified." * * * "The research work carried out in connection with the electrification has included an investigation of the total amount of hydraulic power available."

The reporter for Italy, Mr. Alfredo Donati, states:

"The new program for the extension of electric traction in Italy which was drawn up by the Administration of the Italian State Railways in common with the Government, anticipates the electrification of about 2 800 miles of railway which has been selected with care from amongst those which, owing to their gradients and their heavy traffic, now consume the greatest quantity of coal."

It was stated that this program when completed will effect an annual saving of about 1 250 000 tons of coal and a consumption of about 600 000 000 kw-hr. of current per annum, the greater part of which will be generated by water power. This program, however, is not altogether to save coal, for, later, it is stated that, on certain of the lines to be electrified, the limit of traffic which could be carried by steam traction, had been attained, and electrification had become necessary for increasing the carrying capacity of the lines; also, that, on a number of Italian lines, electrification has been hastened on account of the difficulties of steam operation through the numerous tunnels.

The Federal Railway Commission of Switzerland, reporting to the International Congress, concludes with the following statement:

"The electrification of the Federal Railways is an economic necessity, and ought to be brought about if regular working at all times and under all conditions is to be assured. We must not forever remain dependent on foreign countries, which may withhold their coal, or at any rate dictate their prices without consideration for us. Of the total imports in 1920 (approximately 991 700 ton), 303 914 ton, or 30.5% came from England, and 553 986 ton, or 55.9%, from America, while our former principal sources, Belgium, the Sarre Territory, and the Ruhr Valley, only delivered to us altogether 65 500 ton, or 6.6 per cent. This fact shows on what casual conditions our coal supply, and, consequently, the working of our railways, depends, without taking into account the disturbing factors arising out of strikes, transport difficulties, etc."

France, according to M. Sabouret, Chief Engineer, Technical Department of the Orleans Railway, Reporter to the International Congress, has an ambitious electrification program. In addition to some electrification already completed, and the program for the State-owned railways, the Orleans Rail-

way Company has a program for the electrification of 1 240 miles of railroad, the Midi Railway for 1 680 miles, and the Paris-Lyons-Mediterranean Company for a considerable mileage.

The Orleans Railway will use largely hydro-electric power supplemented with some steam-generated current from a station near Paris; the Midi Railway will use largely, if not exclusively, hydro-electric power; the Paris-Lyons-Mediterranean Company will obtain its principal sources of current from hydro-electric plants on the Upper and Middle Rhône River. All three railways will develop their own power, and, in some cases, the developments will be made jointly with the State-owned railways. These three railways have under consideration a plan for the joint development of hydro-electric power on the Truyère River, in which the development would exceed 200 000 h. p., the supply being exceptionally regular. The plan is to divide the power between them in such a manner as to supplement for each railway the minimum power from its own stations during periods of low water. The reporter says:

"The flow of the watercourses of the Central Plateau is complementary to those of the Alps and Pyrenees; the Truyère will feed the Rhône and Garonne basins during the winter, and the Central Region during the summer. This large programme of the organization of hydro-electric energy shows clearly the obligation imposed on the three companies of associating themselves in a work of unification required in the National interest and to promote the linking up of the three great producing districts."

These references are illustrative of the development of the electrification of railroads in other countries; they appear to indicate the probability that hydro-electric power, by virtue of its cheapness and other qualities, has been more of a factor in extending electrification in foreign countries than it has been in the United States.

The Pacific Coast, with its vast hydro-electric power potentialities, seems to present favorable conditions for the electrification of steam railroads. The power possibilities are probably in excess of commercial and industrial needs and are likely so to continue, whereas coal and fuel oil supplies are becoming more costly and less certain. The topography of much of the country traversed by the railroads and the extent and character of the traffic result in railroad-operating conditions which probably could be met more economically by electrification than by steam.

In the case of new railroad construction, assuming that, in spite of excessive and oftentimes conflicting regulation of the railroads by Federal and State authorities, capital for new railroad construction can be found, electrification would offer advantages for such lines as have promise of a reasonable volume of traffic. The saving in first cost of water and fuel facilities and in the fewer engine terminals required would be considerable, and it is probable that the location of the line and the ruling gradients adopted would be such as to reduce the cost of construction as compared with a road intended to be operated by steam.

It is possible that the requirements of the Federal Water Power Act may make it impossible to contract for power for periods longer than fifty years at

the most, and together with State regulation of public utility rates, may make uncertain the permanency or uniformity of power rates extending over long periods; if so, the progress of railroad electrification may be somewhat retarded.

The subject of this paper has been covered in such a brief and general manner that no conclusions are warranted. However, it would seem reasonably safe to assume that hydro-electric power would be an important factor in steam-railway electrification under the following conditions:

(*a*).—When cheap and available over such an extended area as would include a large main-track mileage for the individual railroad under consideration.

(*b*).—When supplied from several sources tied together so as to insure reliability.

(*c*).—When it can be contracted for long periods.

(*d*).—When its cost reduced to terms of locomotive tractive effort, is cheaper than that of steam-generated power.

DISCUSSION ON THE WATER POWER PROBLEM

By Messrs. J. M. Howells and M. M. O'Shaughnessy

J. M. Howells,* M. Am. Soc. C. E.—In reference to hydro-electric development in California, the speaker wishes to point out certain fortuitous geological changes of a striking character in the northeastern part of the State. The greater part of such changes took place just prior to the Age of Man and have played an important part in arranging for the recent great developments in that locality. The study by Dr. J. S. Diller and that recently made by Professor W. O. Crosby at the instance of John R. Freeman, President, Am. Soc. C. E., have furnished the geological data for a better understanding of the happenings of such great import in connection with the present work.

The Pit River development of the Pacific Gas and Electric Company and the North Fork of the Feather River development of the Great Western Power Company occupy this territory. Had the topography remained as it was in the beginning of the Tertiary period, the great underground water storage of the Upper and Central Pit River Basin and the great surface water storage site at the head-waters of the North Fork of the Feather River would not have existed to attract the pioneers in hydro-electric development. About a mile south of the Big Meadows Dam, now forming Lake Almanor, a water-shed marked, in those days, the head-waters of the North Fork. North of this, instead of the present high mountains, the land lay in the form of low gently rolling hills that led the drainage north and northwesterly to the Sacramento River. The surface or country rocks of this section were mostly sedimentary.

Epoch-making events which marked the late Tertiary period moved the boundary of this water-shed north until more than 500 sq. miles of additional area became tributary to the North Fork of the Feather River and to the site of the Lake Almanor Dam. Great eruptions in the Lassen Peak District caused this change, and imperfectly fluid lava built up high mountains there, thus forming the high Lassen Peak Ridge and adding its eastern and southern slopes to the Feather River drainage. Thus, not only was additional area furnished, but also heavy precipitation and run-off were assured by virtue of the resulting lofty elevations. The great reservoir site of Big Meadows, however, was not formed until extensive and repeated floods of fluid basaltic lava, emerging from many vents, had covered not only a large part of the 500 sq. miles of the new drainage basin, but also 200 000 to 300 000 sq. miles farther north. Subsequent faulting depressed the Big Meadows section below the general plain and formed a natural lake of, perhaps, 25 000 acres, which was furnished with an impervious lining, by erosion from the surrounding country. Erosion continued until a notch was cut in the basaltic dam of the lake. This notch has been restored recently by comparatively feeble human effort, and Lake Almanor has resulted.

From this reservoir site, the Sierra Nevada Mountains extend to the southeast and the Cascade Mountains to the northwest, Lassen Peak being the

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* Chf. Engr., Western Canal Co.; Cons. Engr., Great Western Power Co., San Francisco, Calif.

southernmost of the latter and Lake Almanor forming the dividing line, separating the two great mountain ranges. The Cascades or water-falls themselves, from which the range takes its name, were caused by the hard basalt which generally lines the beds of the streams of this district and refuses to yield readily to erosion, thus causing their flow to fall in cascades.

To the north and northeast of Lassen Peak lay the basin of the Pit River, its northern boundary being just south of the Oregon line and reaching from Mt. Shasta on the west almost to the Nevada line on the east. This drainage area is in large part a basaltic plain and, where sealed by the deposits of erosion, furnishes reservoir sites. Many of these sites, however, are so large as to be out of proportion to their water supply, and, therefore, are more useful for agriculture than for water storage. Reservoirs of another form are abundant, namely, the great natural underground reservoirs which equalize the flows of such tributaries of the Pit River as Hat Creek and Fall River. Over great areas and along these streams, basaltic lava lies as if it had cooled only yesterday. It is shattered and barren and stores all precipitation as fast as it falls and conveys other streams as well. Entrapped water sinks to some impervious stratum and finally issues in great springs of remarkably even flow. The importance of this for hydro-electric purposes may be better understood when one realizes that at the point where Hat Creek enters the Pit River, it has a mean flow of about 650 sec-ft., that Fall River has a flow of 1 400 sec-ft., and that the maxima and minima flows of these streams differ by less than 15% from the mean flows. With such a great and evenly delivered water supply and a fall, in about 60 miles of river, of more than 2 000 ft., one can understand what inspired this development by the Pacific Gas and Electric Company.

The Pit River plants will include three additional developments on the main stream, all possessing a greater minimum flow than the combined flow of Hat Creek and Fall River, but as these developments take their water from the main stream below those tributaries, they also partake of the unregulated flood flow of the greater Pit River basin which is not so fortunate in underground storage, but which possesses opportunities for surface storage.

The drainage area to the south, which the Tertiary period made tributary to the North Fork of the Feather River, also possesses ground-water storage, so that the normal low flow from the new 500 sq. miles of area is at least 40% of the entire river at Oroville, Calif., where 3 600 sq. miles of drainage area reaches the plane of the Sacramento Valley. In addition to this large flow of ground-water, a large flow of surface water is yielded by the new basin. Both supplies now feed Lake Almanor, the main storage reservoir of the Great Western Power Company. This reservoir has a present capacity of 300 000 acre-ft. and, by a 40-ft. addition to the dam, a contemplated capacity of 1 250 000 acre-ft. It has an ultimate proposed spillway level of 4 500 ft. above the sea and is expected to serve eight successive power sites, the tail-race of the lowest being only 160 ft. above sea level. Thus, there is a total gross drop between lake surface and final tail-race of more than 4 300 ft.

This new drainage basin with its auxiliary—Butt Creek—when both are regulated by the ultimate dam, will yield a constant flow of 1 195 sec-ft.

When used in conjunction with the greater unregulated basins which are tributary to the five lower river sites, this great regulated water supply finds its greatest value.

Of the eight plants proposed, Plant No. 7 is nearly completed. Although occupying only about one-tenth of the total drop, this plant, since the commencement of operation in 1908, has led in size any hydro-electric plant west of the Mississippi River. Pit River Plant No. 1 which has recently been completed, however, by the Pacific Gas and Electric Company, exceeds by nearly 10% the size of Plant No. 7. At Site No. 2, the Great Western Power Company recently began an ultimate installation of 135 000 kw., 40 000 kw. of which is at present in operation.

M. M. O'Shaughnessy,* M. Am. Soc. C. E.—The first power plant in Northern California was built more than 32 years ago by the Sacramento Gas and Electric Company, under the management of Mr. H. B. Livermore. A canal built by prisoners from Folsom Prison, diverted water from the American River so that a head of 55 ft. was obtained. The transmission plant was completed from Folsom to Sacramento, a distance of 22 miles, and power was delivered on September 1st, 1895.

In the same year, the second plant, consisting of two 375-kw. generators wound for 5 500 volts, was undertaken on the South Yuba River about 5 or 6 miles above Nevada City, to supply power to the mines at Grass Valley and Nevada City. Since that time, the power industry has received a marked impetus, so that, in 1921, the four largest companies furnished power, as follows:

	Kilowatt-hour sales.	Revenue.
Pacific Gas and Electric Company.........	1 021 820 689	$22 898 046
Great Western Power Company............	340 060 361	5 947 710
San Joaquin Light and Power Corporation.	313 791 835	5 084 780
Southern California Edison Co............	840 081 210	15 074 480
Total	2 515 754 095	$49 005 016

This power is retailed to consumers at an average rate of 1.95 cents per kw-hr., or, deducting the amount paid in taxes, 1.75 cents per kw-hr.

The total hydro-electric horse-power in operation by the two municipalities of Los Angeles and San Francisco, at present, is 88 450 and by thirteen private companies, 911 465, making a total of 999 915.

There are under construction, at present, an additional 142 660 h. p. by municipalities and irrigation districts and 228 150 h. p. by private companies, or a total of 370 810 h. p., all of which will be installed within 2 years, and, at that time, will make a grand total for the State of 1 370 725 h. p.

The possible developments of power companies, which are financially feasible within the next 20 years, include about 4 000 000 additional h. p. These developments will not exhaust all the possibilities of the State, which may be closely estimated at from 8 000 000 to 9 000 000 h. p.

* City Engr., San Francisco, Calif.

The uses of the water of the State may be considered in the following order:

1.—Domestic use for the inhabitants.

2.—Irrigation uses for farm lands and orchards.

3.—Use of water for hydro-electric power purposes.

In some fortunate instances, the combination of all three uses may be obtained from the same drainage area.

The physical topography of the high mountains, with the limited reservoir basins and steep gradients of the river beds, makes the problem of selection of effective reservoirs difficult. The few natural lakes in the Sierra Nevada Mountains suggest the most feasible sites. They possess the advantage of freedom from silting which is incidental to foot-hill reservoirs. The climatic and topographical features of the State regulate the run-off of the streams quite differently from any of those in the Mississippi or eastern coast drainage areas.

Tuolumne River has an average annual flow of 2 040 000 acre-ft. from a drainage area of 1 548 sq. miles. This drainage area extends from an elevation of 300 ft. easterly, for a distance of 80 miles, to an elevation of 10 000 ft. On the higher level, above 4 000 ft., there are numerous natural lakes hemmed in by granite. The floods in the lower reaches to an altitude of 3 000 ft. are developed by winter and spring rains which occur from November to March. The second series of floods occur in May and June, and are caused by the melting snow, which may be as much as 15 to 20 ft. deep on the 6 000-ft. level. The 5 000-ft. contour is the approximate zone of maximum precipitation which diminishes at the crest of the Sierra Nevada Mountains.

The first development in this basin was made by the Turlock and Modesto Irrigation Districts. A concrete dam 127 ft. high was constructed at La Grange to elevate the water in the river bed and divert it by two canals to the irrigated areas of 165 652 acres inside the Districts, extending from Elevation 300 to Elevation 40, on the San Joaquin River. Heretofore, only two reservoirs with a storage capacity of 76 000 acre-ft. were in use along the canals to balance the flow of the river. A new dam at Don Pedro is now being constructed to create a reservoir with a capacity of more than 250 000 acre-ft. to supplement the supply.

Since 1914, the City of San Francisco has been actively constructing storage works in the higher levels, including the Hetch Hetchy Dam, with an initial storage of 206 000 acre-ft and ultimate storage of 348 000 acre-ft., and Lake Eleanor Reservoir, with an initial capacity of 28 000 acre-ft. and ultimate capacity of 168 400 acre-ft. Even with those projected works completed, there will be only about 800 000 acre-ft. in storage for a river that fluctuates annually between a minimum of 895 000 acre-ft. and a maximum of 3 700 000 acre-ft.

A consistent effort, however, has been made to develop storage on this drainage area, in favorable contrast to the Merced River, immediately south, which passes through the Yosemite National Park, with an average annual run-off of 1 228 000 acre-ft., and has storage for only one-third of 1% of its average flow, and the Stanislaus River, immediately north, with an average run-off of 1 380 000 acre-ft. and only about 10% of this volume in storage.

Only three of perhaps forty rivers in California have been mentioned, that are capable of economic development. This situation discloses the great opportunity for the hydraulic engineer, the financier, the philanthropist, and perhaps the State, to undertake the conservation of waters so that the greatest good can be accomplished to the 10 000 000 acres of land capable of irrigation in California, of which to date only 6 000 000 acres have been brought under irrigation. A solution of these problems is being sought by the so-called Water and Power Act to bond the State for $500 000 000 for this purpose. There are fundamental objections to this Act, which make it a dangerous measure to adopt, but the speaker has hopes that from the discussion of it, a sane measure will be evolved, which will do justice to the future of California and increase the prosperity which is now being developed from its civic, manufacturing, and agricultural activities.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

EXPERIMENTS WITH MODELS OF THE GILBOA DAM AND SPILLWAY

Discussion*

BY GEORGE G. HONNESS, M. AM. SOC. C. E.

GEORGE G. HONNESS,† M. AM. SOC. C. E. (by letter).‡—The authors briefly state that 186 different experiments were recorded, which include flows over 100 different sections. These experiments were started in the early summer of 1919, and were continued until weather conditions in the early winter caused the work to be stopped before conclusions could be reached. A complete reconstruction of the control works and parts of the model was required in the spring of 1920 before experiments could be resumed, and then the experiments were continued until the early fall of 1920. This brief statement is not, therefore, a fair measure of the faithful, painstaking, and ingenious work done by the authors, for which they are to be commended.

As stated in the paper, the original purpose of the construction of the model was to determine the sufficiency of the spillway channel, as it was thought by some that it was more than ample, and that a considerable saving would result by a reduction in size.

The behavior of the model on a scale of 1 : 50, with a maximum flow equivalent to a 6-ft. head over the full-scale dam, indicated that a reduction of both width and depth was permissible. Experiments were then made with a width of channel reduced by 50 ft., with a head equivalent to 6 ft. on the full-scale dam, and the results are shown in Fig. 4.§ This shows that the reduced channel, with assumed flood flows, would probably be ample.

* This discussion (of the paper by R. W. Gausmann and C. M. Madden, Associate Members, Am. Soc. C. E., published in September, 1922, *Proceedings*, and presented at the meeting of October 4th, 1922), is printed in *Proceedings*, in order that the views expressed may be brought before all members for further discussion.

† Dept. Engr., Board of Water Supply, New York City, Grand Gorge, N. Y.

‡ Received by the Secretary, October 5th, 1922.

§ *Proceedings*, Am. Soc. C. E., September, 1922, p. 1510.

The flood flow of Schoharie Creek, at Gilboa, in 1869, was the highest in the memory of the then oldest inhabitant. It seems fair, therefore, to assume that the flood of 1869 was the highest in more than 100 years. A fair determination of the quantity of that flood at Gilboa was 44 100 cu. ft. per sec., or 140 cu. ft. per sec. per sq. mile, from 314 sq. miles. As stated, the channel of reduced size was shown to be ample for a flood of 51 381 cu. ft. per sec., or 163 cu. ft. per sec. per sq. mile. Notwithstanding, the channel is to be constructed as originally planned, for the reasons stated in the paper.

A more important fact than the capacity of the channel was determined by the initial experiments. With a section as originally designed, having steps of unusual height and width of tread for an overfall section, the flow passed over the crest, down the first riser, over the tread, and then the sheet of water missed the next three or four steps, falling as much as 80 ft. Hence, the necessity of continued experiments until an overfall section could be selected, which would lead to the falling sheet impinging on each successive step and thus dissipate the energy of the falling water. This was finally accomplished by placing deflecting vanes on the tread of the upper step and modifying the height and width of the other steps.

The writer concurs in the authors' conclusion, that notwithstanding the fact that the behavior of models will not be exactly similar to their prototypes, the model remains the best means of determining the design of many hydraulic structures. This conclusion is based on experience with models used to determine the probable behavior of full-scale structures in the following instances.

Boonton Dam, Boonton, N. J.—The overfall section of this dam was located on the northerly side of the valley, so that the maximum height was not in excess of 70 ft. This required the spillway channel to make an acute angle with the axis of the dam, in order to lead the waste water to the old stream bed. The overflow from the northerly one-third of the waste weir is caught on a steep, sloped channel the maximum grade of which is parallel to the axis of the dam. The water, flowing over the steep slope, has its velocity accelerated, and this deflects the water passing through the southerly two-thirds so that it follows the axis of the spillway channel. A model was constructed to scale, and the plans were perfected after studying the action of the water passing over the model. As constructed, the channel has served its purpose, and the behavior is substantially the same as the model.

During construction, the channel was advanced so that it could be used during the winter season to care for water passing over the overflow section which, as the end of the working season approached, was in such a condition that a concentrated flow over a small section of its length would pass into the channel. A model was constructed as the conditions existed, and flows over it showed that the side of the channel would be overtopped and serious damage likely to result. A modification which increased the length of the temporary overflow section several times was tried, and the contractor was required to advance the work sufficiently to bring about the conditions desired. Overflows during the winter and the following spring did no damage.

Cross River Dam, Katonah, N. Y.—Slight modifications of the waste weir and spillway channel of this dam were determined from experiments with a model section.

Ashokan Reservoir Waste Weir, Ashokan, N. Y.—The spillway channel changes the direction of flow so that it makes a right angle with the line of the waste weir. The north retaining wall contained a re-entrant angle which deflected a part of the flow, so that it impeded the flow of that part of the water moving parallel to the waste weir section. A discharge due to a head of slightly more than 1 ft. on the crest of the weir, made it apparent that modifications were necessary to meet conditions of larger flows which were to be anticipated. A model on a scale of 1 : 50 was constructed, and from its operation it was decided to remove the re-entrant angle and construct a guide-wall in the center of the channel at the right-angle bend in its alignment. Since this work has been done, no overflow has occurred, but it is predicted that the channel will perform its purpose more efficiently than as originally designed.

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PAPERS AND DISCUSSIONS

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ENGINEERING GEOLOGY OF THE CATSKILL WATER SUPPLY

Discussion*

By Messrs. Alfred D. Flinn, George G. Honness, Lazarus White, Walter E. Spear, Arthur S. Tuttle, Louis L. Tribus, E. G. Haines, and X. Henry Goodnough.

Alfred D. Flinn,† M. Am. Soc. C. E. (by letter).‡—The geographical extent of the Catskill Water System and its vital importance to a great community, added to the diverse geological features of the region, make this paper one of unusual interest. In passing, the writer would express his conviction, based on thirteen years' connection with the work described, and as many more years with other large projects, that the municipal authorities of the City of New York were fortunate in their geological advisers and in the fact that Chief Engineer J. Waldo Smith, Mr. Sanborn, and other engineers on the staff possessed knowledge and appreciation of geology. The paper is so complete in its description and so instructive in its correlation of engineering location, design, and construction, with geological exploration and interpretation, that the writer will simply emphasize a few general considerations.

That geological aid pays in constructional as well as in mining operations is believed to have been demonstrated. For greatest results in economy and security, it is essential that:

1.—The engineer and geologist should co-operate from the beginning of the preliminaries of the project.

2.—The geologist should be well informed on the broad geology of the region, the detailed structural geology of the location, the mineralogy of the

* This discussion (of the paper by Charles P. Berkey, Esq., and James F. Sanborn, M. Am. Soc. C. E., published in September, 1922, *Proceedings*, and presented at the meeting of October 4th, 1922), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† Secy., United Eng. Soc., and Director, Eng. Foundation, New York City.

‡ Received by the Secretary, September 26th, 1922.

rocks and the overburden of earth, and the present and ancient water circulation, or drainage.

3.—The geologist should have some comprehension of the nature and requirements of the structures and excavations making up the works of the project.

4.—The engineer should have some knowledge of geology and mineralogy.

5.—Even routine field explorations (soundings, test-pits, borings) should not be delegated to an assistant lacking understanding of the importance of each feature of such explorations. Every step requires the intimate supervision of an engineer possessed of knowledge of geology and keen appreciation of the importance of carefulness, close observation, and complete records, with clear, full headings and dates.

6.—The owner (or other person having control of the general policies) must have foresight and courage to spend enough money to obtain adequate information and make a thorough study of the facts gained.

7.—Full use should be made of the geological information and deductions in the design, location, and method of construction.

8.—All geological information, with suitable explanations and safeguards, should be made accessible to intending bidders, who should be required to examine such information while preparing their bids. Exhibits for bidders should include not only maps, sections, and statements, but also test-pits and materials removed from them, cores, and other samples from borings (all of them, or as many as practicable), and every other physical object of contributory value, supplemented, if advantageous, with photographs.

9.—The geological information should also be accessible to the engineers and contractors during construction.

All these statements are somewhat obvious, but the results achieved on the Catskill Aqueduct work show many advantages which may be realized by the proper utilization of the skill of the geologist as an adjunct to good engineering.

George G. Honness,* M. Am. Soc. C. E. (by letter).†—This paper is particularly interesting to those who were associated with the authors in conducting the work by which the geological information was secured. It also should be of value and interest to the Engineering Profession in general.

The part of the paper covering the work from the Ashokan Reservoir to the Atlantic Ocean is so complete, being based not only on the knowledge gained by borings, but also by the actual construction, that little can be added. The work on the Schoharie development is not so fully covered, as the authors did not have personal knowledge of the later investigations and the progress of construction. The writer, therefore, will try to add something gained by knowledge of the actual construction work.

Schoharie Reservoir and Gilboa Dam.—The sub-surface investigations for a site at which to construct a dam to form the Schoharie Reservoir extended from Pratt Rocks to Gilboa and located the pre-glacial gorge for a distance

* Dept. Engr., Board of Water Supply, New York City, Grand Gorge, N. Y.

† Received by the Secretary, October 5th, 1922.

of six miles; everywhere the gorge below the floor of the old valley was filled with material which may be considered as generally impervious. The course of the old gorge was sinuous; near Devasego Falls, and, again, at the site of the Gilboa Dam, it makes a complete letter "S"; in the vicinity of Manorkill Falls, there was apparently an abrupt drop in the floor of the gorge and probably a "fall" existed in the pre-glacial stream. At Gilboa, the bottom of the pre-glacial gorge is at least 130 ft. lower than the post-glacial. The lowest part of the gorge is westerly from the limits of any engineering structure and is covered to a great depth by a very impervious clay. An investigation was conducted to determine the possibility of a filling of pervious character of wide extent in the bottom of the valley up stream from the dam. After making a number of special borings, it was concluded that if exposed rock adjacent to the dam was covered by earthy material deposited through water, no appreciable loss of water need be anticipated. Subsequently, in excavating the core-wall trench, it was concluded that the excavation was passing close to the south side of one of the steps of the pre-glacial gorge, and that some of the talus pushed off the sides of the old gorge by advancing ice had been penetrated. For a part of the distance, the core-wall extends to rock, and from where it leaves the rock to the known limits of this pervious material, an effort will be made to consolidate it by grouting.

The authors enumerate the "Geologic Conditions Affecting Dams", and it may be of interest to outline the methods used to determine the extent of the excavation for, and the treatment of, the foundation of the Gilboa Dam. The borings made for the preliminary investigation of the dam site, and also those made later for use in planning the structures, are shown on Fig. 5* of the paper; many of these borings were deepened, those on the hillside being carried down to the level of the floor of the valley and those in the bed of the present stream to a depth of 100 ft.

Pressure tests were conducted to locate seams in the rock, and to determine their extent and their approximate water-carrying capacity when subjected to a pressure equal to that which would result from a height of 10 ft. of water over the crest of the dam. An apparatus similar to that used on other investigations made it possible to segregate each vertical foot of the diamond drill hole, to subject it to a pressure, and to make a volumetric determination of the quantity of water pumped. These tests showed that, in general, considerable leakage occurred in the upper part of the holes near the surface of the rock, both through vertical and horizontal seams; the number of seams and quantity of leakage decreased as the depth increased. When a test of one hole was in progress, observations were made in adjacent holes to determine the extent of leakage planes. No extensive leakage planes were detected; in some cases, however, responses were obtained in holes 400 ft. away. Seams were located both in the shales and in the sandstones, but they were more clearly defined in the sandstones.

In order to analyze and visualize the results of the test, a model was constructed, the outline of the dam and spillway being in plan. At the loca-

* *Proceedings*, Am. Soc. C. E., September, 1922, p. 1547.

tion of diamond drill holes, wooden circular rods were inserted and painted to indicate the various stratifications of rock. A blueprint showing the results of pressure tests was attached to the rods by thumb tacks at the proper position; cords leading from rod to rod showed the water circulation between holes and its direction. From a study of the results, a tentative depth for the general foundation of the dam and of the bottom of the cut-off excavation was fixed, and the depths to which to extend diamond drill borings for grouting were determined.

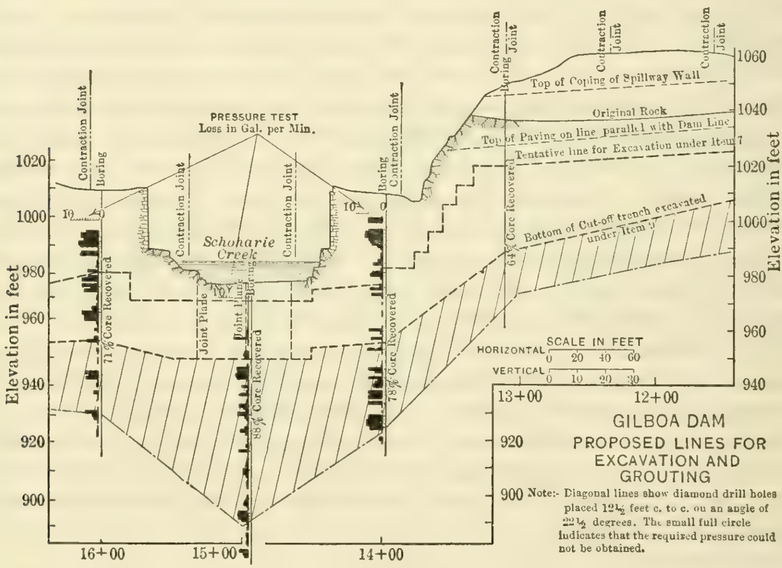

FIG. 18.

Fig. 18 shows a part of the profile which was issued to the field engineers as a guide to excavation. The line for excavation under Item No. 7 was tentative, because it indicates the extent of the excavation for the foundation of the dam, which was dependent on conditions disclosed as the work progressed. The line for excavation under Item No. 9 indicates the bottom of the cut-off trench, and is carried below the zone of seamy rock. Core borings inclined at an angle of $22\frac{1}{2}°$ with the vertical, were made for the purpose of intersecting heading joints and planes and thereby causing more effective circulation of the grout. The diamond drill holes were extended to a depth below which the pressure test showed there were only slight seams which carried off very little water.

The grouting is not done until masonry has been placed in the cut-off trench and to a substantial depth over the entire foundation of the dam. Steel pipes are caulked into the diamond-drill holes and carried up with the masonry. Fig. 18 shows much of the information on which conclusions were based.

Perhaps the most interesting geological feature to the general public disclosed by the work in the vicinity of Gilboa was the finding of fossil trees of the Devonian period, said to be the oldest flora of the earth's history. The first fossils were discovered several years ago when a section of State highway was under construction. Dr. John M. Clarke, of the State Museum of the State Department of Education, asked that a lookout be kept for specimens as the work progressed. Before the construction had progressed far enough to disclose any fossils, representatives of his Department discovered some very good specimens at Manorkill Falls at about Elevation 1 120. As the excavation for the dam progressed, other specimens were found at Elevation 1 020 and at the quarry for facing stone at Elevation 960. In each instance, they were bedded on a thin layer of dark shale which represented what was left of a black muck swamp in which they originally grew. These fossils are said by the geologists to be 100 000 000 to 300 000 000 years old and are the only specimens yet found. A large collection has been placed in the State Museum at Albany, N. Y. Specimens are also in possession of the Harvard University Museum and the American Museum of Natural History in New York City.

Shandaken Tunnel.—The preliminary investigation of sub-surface conditions disclosed that each small valley crossed by the line of the tunnel had its own particular gorge and the investigation was sufficient to ascertain whether the pre-glacial gorges were deep enough to reach the grade of the tunnel, which occurred in only one case.

If the tunnel had been constructed on the hydraulic gradient at the Bear Kill Gorge it would have penetrated the filling of the gorge, a disconcerting occurrence in tunnel construction. To avoid the possibility of this, the tunnel was depressed so that there would apparently be a rock roof 100 ft. thick at the Bear Kill Gorge. The Shandaken Tunnel, therefore, acts as a pressure tunnel for about 3½ miles of its length.

It was the judgment of all who had studied the borings that comparatively little support would be required and that where it was necessary it would be temporary, merely to protect the workers from small fragments spalling off. The condition encountered required that about 50% of the tunnel should be supported by either temporary or permanent timbering. The exposure of the red shales and sandstone to the atmosphere caused masses of sufficient size to fall, and secure protection was necessary. In the gray sandstone, "popping rock" which was observed at Hudson River shafts and other parts of the aqueduct, occurred, particularly in the north tunnel from Shaft 5. This rock appeared to be of the best texture and sound, but it required permanent support. After the heading and the tunnel for a distance of 100 to 200 ft. from the face of the heading had been excavated, it was common to hear a loud report and then a large slab of rock would be observed to loosen. These occurrences caused a panicky feeling among the men, as frequently large pieces of rock fell shortly afterward. After the timbering had been erected and dry-packed, the "popping" was no longer noticed. With the strain removed, it is problematical whether further working of the rock would have taken place, but the chances were too great, and support was carried as close to the heading as practicable.

A few crushed zones have been encountered, but they have been passed without much trouble. In the south tunnel, from Shaft 3, a horizontal clay seam, surmounted by a badly broken up bedding of shales, was encountered, and the inflow of water reached a maximum of 170 gal. per min. As the heading was advanced and heavily timbered, several crushed zones were passed where the stratification was tipped up and very blocky and, finally, a mud seam, varying from 5 to 7 ft. thick, crossed the line of the tunnel. This was possibly a decayed rock or, perhaps, a pre-glacial residuary decayed material, although, at that depth, it seems hardly possible. For the next 100 ft., three badly crushed zones were penetrated. The rock was broken by cross-joints and shrinkage planes, many of which dripped water and were filled with a bluish clay. The disintegration of the red shaly sandstones and the filtering in of the clays give the appearance of a mixture of red and gray shales. Beyond that point, the conditions become normal.

In the north tunnel, from Shaft 4, about 3 600 ft. from the place just described, a crushed zone which gave much trouble was penetrated.

In the north tunnel, from Shaft 5, a small crushed zone and slight faulting was found, and, at one place, a badly disintegrated rock. Gas in small quantities entered in a number of places, and Plutonic water having a solid content three times that of the water of the Atlantic Ocean and one-half that of the water of the Dead Sea has been found, that was undoubtedly entrapped and held in cavities at the time the rock was being formed.

At present only 4 000 ft. of the 18.1-mile tunnel remains to be excavated, and it is unlikely that more serious troubles than those described will arise.

At the southerly end, a short stretch of tunnel in earth is to be excavated, that presents many of the difficulties of soft ground work. The adoption of careful soft ground methods by an expert on that kind of work gives assurance that it will be successfully completed.

The tunnel has been remarkably dry, the maximum quantity of water pumped at any one time from one shaft being about 170 gal. per min.

The authors state in a number of places that, generally, the strata in the Catskill region "dip to the west at a slight angle". It has been found that the dip is from 1° 30′ to 2° in a southerly direction, consequently, that part of Plate XXII,* covering the Shandaken Tunnel, should be corrected to agree with the determination given.

The character of the rock and the superior equipment and organization of the contractor led to remarkable progress in excavation. With twelve headings being worked, more than one-half of which required timbering, a progress of 5 593 ft. per month was made. The average weekly progress (elapsed time, which includes time lost in re-organization) is 62 ft. of completed tunnel per point of attack, a much higher rate than that maintained on the tunnels of the Catskill Aqueduct. At the shaft, maintaining the best progress, the average was 90 ft. per week.

Lazarus White,† M. Am. Soc. C. E.—The speaker's knowledge of geology gained from Professor Kemp at Columbia University, was valuable, and was

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* *Proceedings*, Am. Soc. C. E., September, 1922, p. 1537.

† Pres., Spencer, White & Prentis Inc., New York City.

used for the first time on this work. It was a great aid in anticipating underground conditions, which is essential in order to locate an aqueduct or dam in a country like that south of the Catskills. The superficial aspect of that country does not indicate the underground structure, which is the result of past geological conditions, and about which a competent geologist can tell a great deal. He cannot tell all about it, and that is where the danger lies. The engineer can co-operate with the geologist, but he must adhere to an independent judgment of the conditions based, not on a geological theory or accepted statements, but on borings. To do otherwise invites the risk of serious error. For instance, on the Rondout Siphon, with which the speaker is familiar, the geological predictions were good, but it would have been dangerous to have located the aqueduct on the basis of those predictions alone, because one of the gorges that the geologists had predicted would be deep, was shallow, and another that they had predicted would be shallow, was deep; if the depth of the tunnel had been determined in accordance with the predictions, a deep gorge would have been penetrated, which would have caused serious difficulties. However, these discrepancies were discovered by diamond drill borings long before the final profile was adopted. It does illustrate, however, that too great a duty should not be placed on the geologist. The location of the Loetchburg Tunnel was left to the geologists, and no borings were made. The result was that the tunnel penetrated a buried gorge, with disastrous results.

There were places on the Rondout Siphon at which a change of profile would have made a great difference in the amount of tunneling in the Hudson River shale and the Shawangunk grit. To determine the cost of tunneling in each of these rocks, two experimental tunnels, side by side, were driven 150 ft. in them. This work furnished valuable information, especially on the method of timbering the shale, and resulted in a large saving, later, in the cost of driving the main tunnel.

In the Rondout Siphon, a particularly bad condition was found in the limestones, and there was no method of locating the profile, to avoid them. One of the geologists predicted very closely the caves that might be penetrated in driving that tunnel; however, those caves were below the gorges. The water circulated down and rose again under pressure, the conditions being similar to those which the same geologist had observed in Missouri. In the speaker's opinion, this paper is a valuable one for engineers, and can be used to great advantage in schools to co-relate the study of geology with that of engineering.

WALTER E. SPEAR,* M. AM. SOC. C. E.—The authors are to be congratulated on their clear exposition of the many problems in engineering geology that arose in the construction of the Catskill Water-Works. Perhaps in no previous enterprise of the same magnitude has there been equal co-operation between the engineers and the geologists.

The Hudson River is the one large stream within the State of New York that reaches the sea without crossing the boundaries of another State. It has been possible, therefore, with the consent of the State, to appropriate its

* Dept. Engr., Board of Water Supply, New York City.

waters for New York City, and no attempt has been made to acquire any source of supply outside the State. The one large tributary of the Hudson River in the vicinity of New York City—the Croton River—was developed as the first large source of supply. It was necessary, however, to obtain the next supply from a more remote tributary of the Hudson River, the Esopus Creek in the Catskill Mountains. The difficulties of conveying the Catskill Mountain supply to the city were those of constructing an aqueduct across the geological formations which, in this vicinity, have a general northeast-southwest trend. If the Housatonic River, which was suggested as a source of supply in 1900, or even the more remote Connecticut River, was in New York State, instead of in Connecticut, the transportation in a direction parallel with the strike of the geological formation would have been simpler than bringing the Catskill supply to New York City.

It can now be estimated that the probable date of exhaustion of the available water supplies for New York City is not very distant. Preliminary investigations, anticipating the acquisition of new sources of supply, have already been started, in which Dr. Berkey has had a part. Now, as before, no works outside the State of New York may be considered and the problems confronting the engineers are the same as those of the Catskill works, namely, constructing reservoirs and building a large aqueduct that will pierce the mountains and cross the deep valleys lying between the city and any large source of supply that may be made available. A new conduit will probably be built in tunnel to a larger extent than the Catskill Aqueduct. However, the experience gained on the Catskill Aqueduct in tunneling, mostly through the same formations as will be encountered on a new aqueduct, gives assurance that, with the same care and thoroughness in making the preliminary investigations, no serious difficulty need be feared.

Something may be added to the statements made by the authors in regard to the investigations on Long Island, looking to the development of an emergency ground-water supply which could be made available in advance of the delivery of the Catskill supply. In 1907 and 1908, in addition to the mapping of the water-table in Suffolk County, the gauging of the streams, and the topographical surveys, the Board of Water Supply made a number of deep borings on the south shore of Long Island along the line of development of the proposed ground-water supply. One of these borings, having a 12-in. stove-pipe casing, extended to a depth of 900 ft.

These borings furnished much additional information on the geology of Long Island and led to the preparation of a plan for pumping a supply of 250 000 000 gal. of water per day from the "yellow gravels" of Southern Suffolk County. Professor W. O. Crosby, the Consulting Geologist on this work, made an exhaustive study of all the available data on the geology of Long Island, which, previous to the work of Messrs. Crosby, Veatch, Bowman, and others in 1903, was, as a whole, a comparatively unknown territory. In his report of 1910, which is as yet unpublished, Professor Crosby confirmed the conclusions, previously reached by the engineers, that, in Suffolk County, the only available water horizon from which to obtain a large supply

was that in the "yellow gravels", which he classified as the Cohansey and Lafayette of the Pliocene, the Pensauken of the Epipliocene, and the glacial outwash of the Pleistocene, and which cover Southern Long Island to a depth of 50 to 200 ft.

He pointed out that the Bethpage gravel of the Miocene, an important horizon in Southwestern Long Island, represented local beds deposited by mainland rivers or, perhaps, by glacial streams, and that these gravels did not exist in Suffolk County, except possibly as offshore deposits and except for a small body of gravel, under the Bethpage clay beds, which has no water-supply importance.

Of other water horizons on Long Island, Professor Crosby's report shows that many successful wells, generally of small capacity, are found in the Magothy of the Cretaceous series within a belt along the north shore in Queens, Nassau, and Suffolk Counties, from Flushing to Port Jefferson, where the water-bearing gravels of this formation lie at elevations referred to sea level of + 70 to — 200 ft., and at a few localities on the south shore in Nassau County, where this gravel was found about 500 ft. below sea level. It was Professor Crosby's belief that the Magothy in Southern Suffolk County contains no gravel, and if it does exist in localities thus far unexplored, it lies beneath such thick beds of impervious sand and clay as to be cut off from the source of supply in the rains that fall on the surface of Long Island.

The lowest water horizon on Long Island, the Lloyd sand (Raritan), also of the Cretaceous series, lies still deeper than the Magothy gravel and not far above the bed-rock. It is a more important horizon than the Magothy gravel and furnishes a large quantity of water at moderate depths of 200 to 400 ft. below sea level on the north shore of the Island, in Queens and Nassau Counties, from College Point to Huntington, and within a zone lying north of that in which wells in the Magothy occur. A few wells have been driven to the Lloyd sand in Southern Queens, where it is found at depths of 500 to 700 ft. below sea level. Professor Crosby pointed out that this horizon derives its supply, as does the Magothy gravel, from the Manhasset and outwash sands and gravels that fill the buried valley of Long Island Sound. If Lloyd sand occurs in Southern Suffolk County, it lies at still greater depths than in Southwestern Long Island, and it is more effectively cut off than the Magothy from the surface sources of fresh-water supply and is probably filled with salt water.

This work of the Board of Water Supply on Long Island is deserving of wider publicity. The knowledge gained there in regard to the deeper water horizons should prevent some unnecessary explorations in the future and the drilling of many useless wells.

ARTHUR S. TUTTLE,* M. AM. SOC. C. E.—The authors have omitted all reference to the work performed by them, a few years ago, in assembling, for convenient examination, records and specimens of all borings in New York City and vicinity. The nucleus of this collection consisted of the boring record made in connection with the development of the Catskill Water Supply, but

* Chf. Engr., Board of Estimate and Apportionment, New York City.

it was reinforced by all other available data that were reliable. The result has been that a vast amount of data has been collected which should be of enormous value in the development of plans for engineering work in this locality. This collection of data is housed on the thirty-fourth floor of the Municipal Building, and it is in such form that any information desired can be readily obtained. It is hoped to add to this collection by securing similar data from work now in progress and from work to be undertaken in the future. The fact that this collection has been made and is under the care of the Chief Engineer of the Board of Estimate and Apportionment is probably not generally known, and the opportunity is taken, at this time, not only to advise that any one desiring such information will know where it can be secured, but also to invite any contributions to the collection, which are now or may be later available.

Louis L. Tribus,* M. Am. Soc. C. E.—The speaker has in mind two cases that might be of interest in showing the advantages of co-operation between the geologist and the engineer. He was sent to take charge of a reservoir that had been previously under construction for about a year. The earthern embankments were partly built and the bottom had been partly stripped. The plans contemplated a clay puddle, 2 ft. thick, as the bottom lining. Six or eight test pits had been dug, which showed a fair quality of loam and clay, with no rock appearing. However, when the bottom was fully excavated, it was found that about three-fourths of it was underlaid with limestone rock having pockets 6 to 8 ft. deep. If a local geologist had been consulted or reasonable borings had been made, many thousands of dollars would have been saved. Concrete had to be used instead of clay puddle for the bottom lining.

Another case came into the speaker's practice a few years ago: A rather important dam had been partly constructed. When the bottom was first stripped, it appeared to be solid, but when the contractors commenced to excavate footings for the concrete, pockets were discovered large enough to hold small buildings, and washouts aided further in contributing knowledge. Owing to an almost complete absence of borings and lack of geological information, the owners spent several hundred thousands, and possibly, directly and indirectly, millions of dollars, to make good the deficiency.

Both the experiences mentioned are helpful in emphasizing the advantage of first obtaining geological data.

E. G. Haines,† M. Am. Soc. C. E.—This paper differs from those usually presented before the Society. Primarily, it describes the work required on a rather extensive underground survey, and the information obtained therefrom. Such underground surveys are made for other engineering works, but they seldom cover as wide an area, nor are the investigations carried to as great a depth. In this case, the investigations were made largely by borings, often several hundred feet in depth (in some cases, as much as 1 000 ft.), whereas, for other engineering structures, a limited penetration into bed-rock is usually sufficient.

* Cons. Engr. (Tribus & Massa), New York City.

† Asst. Div. Engr., Transit Comm., New York City.

The paper presents the results from such borings verified by observations from the actual construction. Few engineers are familiar with the geological history, or even the geological structure, of the section where they are employed. The speaker's attention has been called many times to that fact in connection with borings. He was recently asked to examine a drawing called a boring sheet, which covered quite an extensive area in New York City. At the bottom of a number of holes, "white sandstone" had been recorded and this immediately aroused his suspicions, as he believed it to be limestone. The fact that the same material was shown at the bottom of a number of holes some distance apart indicated a general vein, and not boulders. It is difficult to understand how those who made the borings or recorded them on the sheet could have expected to find a vein of white sandstone enfolded, and in contact with Manhattan schist, which is a metamorphic rock folded and banded, and jointed in every direction, and eroded by glacial action. In this case, there was no excuse for an erroneous classification of the material, as a chemical and physical laboratory was available. The material in question was Dolomite, locally known as Inwood limestone and farther up the Hudson as Tuckahoe marble.

It may be held by some that this error in classification was of little importance, as the material was actually rock. That will not be conceded; the borings were made, not only for the information of the designers of an important structure, but also for contractors expected to bid on the work. At certain localities, the outcrop of Inwood limestone is disintegrated to such an extent that it is used as a building sand, whereas, in underground veins, subjected to water and the acids in the soils, it is sometimes decomposed and resembles clay. Between these two extremes lies the more solid rock, which somewhat resembles sandstone.

The point the speaker wishes particularly to stress is this: If borings are made, the boring samples should be classified by some one competent to interpret them properly. This is not always the case. Many borings have been made in New York City and vicinity, the samples of which are incorrectly classified, particularly wash-boring samples, of which part of the finer material is lost in the process of obtaining the sample.

X. Henry Goodnough,* M. Am. Soc. C. E.—The first work of the geologist in connection with engineering work, that the speaker recalls, was many years ago on the investigation of ground-water supply in Eastern Massachusetts. The case was that of a town which had taken water from the ground near a river and was sued by a riparian owner for damages for diversion of the water. In that case, the town authorities succeeded in proving, with the aid of a geologist, that the stream came underground from the White Mountains, and escaped paying any damage for the water diverted.

The work with which the speaker has had to do recently has been chiefly in connection with studies for reservoirs in the valleys of some of smaller New England streams, tributaries of the Connecticut River. Here, one finds the usual conditions of streams in New England and the eastern part of the United States generally, deep gorges filled with sand and gravel and with rock

* Chf. Engr., Massachusetts State Dept. of Health, Boston, Mass.

on the sides. The determination of the location of the bottoms of these valleys is difficult and, in preliminary investigations, it is often important that the work shall be done without too great expense. In one of these valleys, it was found that the bottom was covered with boulders, some of which were very large, beneath 800 ft. of sand and gravel, but, fortunately, in that part of New England, there is no limestone, and none of the soft sandstone has been encountered in the localities examined. The aid of the geologist was very valuable in these investigations.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

LOCOMOTIVE LOADINGS FOR RAILWAY BRIDGES

Discussion*

By Messrs. Lewis E. Moore, Charles B. Wing, R. O. Stewart, and Henry S. Jacoby.

Lewis E. Moore,† Assoc. M. Am. Soc. C. E. (by letter).‡—Some of the most difficult questions with which railroad bridge engineers have to contend are the probable future increases in loads and whether the useful life of a bridge will be ended before its capacity is exceeded. Engineers hardly could have been expected to foresee or to provide in their bridges for the tremendous increases which have taken place, both in the total weight of locomotives and in the wheel concentrations. To predict what will happen is difficult, but that is no argument for failing to make as wise provision for the future as circumstances and conditions seem to warrant.

For the heaviest present-day loading, the Cooper series does not meet the requirements. Perhaps, few railroad companies at present use locomotives like those on which Mr. Steinman's diagrams are based, nevertheless, the tendency of loads, both total and concentrated, has been upward for a number of years. Any change in loading which better meets the tendencies of locomotive design and which can be used as a more or less general "yard-stick", is an advance. The fact that all lines do not use such enormous locomotives as the maxima treated in the paper, is no reason for condemning the system evolved in it. It is possible to use any part of Mr. Steinman's loadings in any particular case. As to whether Loading Nos. 1, 2, or 3, is used would depend largely on the ideas of the individual engineer. Having the loading in such shape that one can check the resulting stresses by judgment to a certain extent, is, perhaps, to be preferred to a single loading formula, especially as difficulties of computation cannot be allowed to stand in the way of excellence or reasonable accuracy of design.

* Discussion of the paper by D. B. Steinman, M. Am. Soc. C. E., continued from November, 1922, *Proceedings*.

† Cons. Engr., Boston, Mass.

‡ Received by the Secretary, October 7th, 1922.

The omission of electric locomotives from the paper is rather unfortunate, because it seems probable that their use will increase materially in the future, particularly on congested lines with heavy traffic. To see just where the electric locomotive fits among the engines used by Mr. Steinman will be of interest. It would seem that the stress-producing effects of a proposed Norfolk and Western freight locomotive* having four axle loads of 70 250 lb. each, concentrated in a distance of 16 ft. 6 in., with another similar series of loads 22 ft. away, would be somewhere between those of Loadings Nos. 2 and 3, suggested by the author. Accurate computation might not confirm this somewhat superficial conclusion.

The size of the engine governs the length of the train, but it does not govern the weight of the individual car. In most cases any locomotive, however small, that a railroad possesses, is capable of pulling a train of maximum weight per foot, which will fill its longest bridge span, so that whatever variations are made in the locomotive loading, the loading following the tender should be kept to the maximum and should be the same whatever the type or weight of the locomotive. This should be so, irrespective of the location of the railroad, as long as it has trunk-line connections, and, also, of whether the bridge is on a main line or a branch.

The exact trend of locomotive development for the future is problematical, but owing to the present tremendous wheel concentrations and the resulting wear on roadbed and track, it would seem that the limit has been almost reached. This has been said in the past, and yet wheel concentrations have increased. The limits of clearance have now been quite well filled and as the cost of increased clearances is practically prohibitive, it is perhaps more reasonable to say that the limit of individual wheel concentrations has now been reached than it would have been some years ago. When the dimensions of width and height are entirely utilized, only length remains in which expansion can take place. It would seem, therefore, that locomotives may become longer in the future, with perhaps a different wheel arrangement.

Locomotive cylinders and reciprocating parts and rods have become so heavy that development may take place along entirely different and new lines. This might mean the substitution of a vertical high-speed engine of the marine type, probably condensing and compound, geared to the axles, instead of the present enormous pair of single cylinders. Such a construction should have a number of advantages toward the reduction of weight and possible increase in fuel economy, as well as a lower cost for repairs. Such construction would make it possible to install an engine on the tender and so use for tractive purposes a dead weight which must now be hauled with no compensating advantages. Development of this kind would probably result in wheel arrangements somewhat similar to that of the existing electric locomotives. Such locomotives, if properly designed, could be run in either direction with equal facility, thus obviating the use of turn-tables and the periodical increases in turn-table lengths, which have been one of the many difficulties facing railroad engineering departments. The high-speed engines of the marine

* *Engineering News-Record*, September 14th, 1922, p. 437.

type could be made interchangeable so that if repairs were necessary to the engine and not to the boiler, the engine could be removed and another substituted in its place, which would make it unnecessary to tie up the whole expensive machine for repairs to, perhaps, a minor part. A locomotive of the type outlined could be made to have a torque practically as steady as that of the electric motor. The balancing of the engines would be much simplified and the wear and tear on the track and equipment, due to lack of balance, would be practically eliminated.

Railroad motive power executives, if confronted with this development, will say that Trevithick used a vertical cylinder locomotive and discarded it because of the vertical vibration. To those who may raise this objection, the writer will say that Trevithick's engine was not balanced and will also ask them to consider the automobile.

In the desire to prophesy a little, the writer has apparently wandered far from the main subject, but perhaps not so far as may appear. Such a development would result in locomotive loadings which would more closely approach the general characteristics of those given in the paper, although they would not necessarily have such large wheel concentrations. Mr. Steinman deserves great credit for his paper. The writer believes the paper to be progressive and that the system of loadings proposed by the author will be quite generally adopted.

Charles B. Wing,* M. Am. Soc. C. E. (by letter).†—The author has performed a valuable service in showing the discrepancies existing between stresses obtained by using the Cooper E-system of engine loadings and those caused by seven types of engines now in quite general use. Calculated static stresses in railroad bridge structures subjected to train loads serve two purposes:

First.—To form a judgment as to the safety of structures now in use.

Second.—To form a basis for the design of structures yet to be built.

Engineers charged with the responsibility of maintaining existing structures stressed by new types of locomotives of increased weight, naturally choose the wheel-load method of analysis and for this purpose use the wheel concentrations and spacings belonging to the heaviest engine operating on the division on which the structure is located. In the writer's opinion, no system of engine excess or equivalent uniform load analysis is as satisfactory for this purpose as the method of using the actual wheel loads and spacings of the heaviest engine in operation.

As a basis for designing new structures, it is advisable to look forward to probable changes in engine loadings. If, as the author contends, the present standard Cooper E-system is no longer adequate, a new standard should be adopted. The author's proposed M-system of loadings is worthy of consideration and may prove to be the needed modification of the Cooper E-system.

The determination of the static stresses in the members of bridge trusses, due to a system of moving concentrated loads, is a comparatively simple

* Prof., Structural Eng., Stanford Univ., Palo Alto, Calif.

† Received by the Secretary, October 7th, 1922.

problem of analysis.* Stresses thus obtained, properly modified for impact, form a safe and satisfactory basis for bridge design.

The writer can see no advantage to be gained by the adoption of either of the substitute systems mentioned by the author. The difficulties of wheel-load analysis mentioned by many writers in the past are more imaginary than real. Given a moment diagram and a fair knowledge of stress analysis, the time consumed by either of the proposed systems of analysis is approximately the same. As the proposed substitute systems are based on the actual wheel concentrations, there seems to be no good reason for their preference.

R. O. STEWART,† ESQ. (by letter).‡—The author has chosen those few types of locomotives, which produce peak points on a moment curve, and has compiled a series of arbitrary loadings which will approximately give an enveloping moment curve for such peak points. There is nothing new or unusual about the two alternative methods of handling this arbitrary loading, and these alternatives do not require or merit special consideration, as the same principles can be applied to any conventional system of concentrated loadings.

The essential requirements of a standard bridge loading for any given railway are, as follows:

(*a*).—One standard system of conventional loading must be used for all bridge structures, such loading to be increased or decreased in fixed ratios for heavy or light structures. For purposes of design this requirement is desirable and, for the classification of old structures, it is essential.

(*b*).—The basis of any standard bridge loading should be an average of the heaviest of the existing or probable locomotives in greatest common use on the railway, or, in other words, the standard loading should be designed to give the most economical structure possible for the class or strength of structure most generally required. The standard loading should also be such that proportional increases or reductions of it will produce the smaller number of heavier or lighter structures, without too great a sacrifice in economical design.

(*c*).—As the tendency has been (and may possibly continue to be) for the weight of rolling stock to increase slowly, the standard loading should tend to be more nearly normal to the heavier rather than to the lighter existing or probable locomotives.

On the basis of these requirements for a standard loading and considering not one railway, but the majority of American and Canadian railways (the customary types of locomotives being somewhat common to both countries), the writer would consider Mr. Steinman's proposed standard loading at fault in the following respects:

(*a*).—Rather than being based on the heaviest of the regular standard types of locomotives in common use on the majority of average railways, the loading has been designed to cover only the unusually heavy locomotives among a few railways. These locomotives are probably operated only on

* "General Criterion for Position of Loads Causing Maximum Stress in Any Member of a Bridge Truss," by L. M. Hoskins, *Transactions*, Am. Soc. C. E., Vol. XLII (1899), p. 240.

† Asst. Engr. of Standards—Bridges, Canadian National Rys., Grand Trunk Pacific Ry., Toronto, Ont., Canada.

‡ Received by the Secretary, October 18th, 1922.

restricted districts where special design provisions could readily be made for the particular heavy locomotives involved.

(*b*).—Contrary to Mr. Steinman's contention, this loading cannot be reduced in fixed ratios, in a manner similar to the Cooper loading, to suit properly the requirements of railways operating only lighter locomotives or to suit the requirements of various intensities of loading necessary on different sections of any one road.

The author's M-60 is a fair loading for any railway operating locomotives of the Erie Railroad Class, P1, 2-8-8-8-2, the Virginian Railway, Class 2-10-10-2, and the Pennsylvania Railway, Class N-1-S, 2-10-2, the train load being 6 000 lb. per lin. ft. in each case. However, this is the one and only condition in which the use of this loading is fair or economical. For a railway operating only one or two of these heavy classes of locomotives, the author's loading is not correct.

Mr. Steinman states that "this loading can be increased or reduced in fixed ratios in the same manner as the Cooper system of loading". The bulk of the bridges of the Canadian National Railways are being designed to carry economically the Santa Fe T-1-c, Mikado S-1-e, Consol N-2-a, and Pacific J-7-c locomotives, and the writer thinks that these four classes of locomotives represent quite fairly the general loadings of the average Canadian and American railway. These locomotives do not fit the author's loading nearly as well as they do the Cooper loading, except possibly up to spans of 150 ft. In addition to this, the Canadian National Railways has a number of branch lines for which it is unlikely that any but the lighter locomotives will ever be required. The author's loading is at its worst for these light locomotives, whereas the Cooper loading is at least a fair approximation, considering that the number of new bridges required for such loading is small compared with those required for the heavier locomotives.

The writer does not think that the Cooper system of loadings is perfect, or that it cannot be improved. Quite an extensive study of this matter was made in 1921, using the locomotives of the Canadian National Railways. Although several systems of loadings were devised, which were considerably more normal than the Cooper system, to the heaviest locomotives, it was decided that, at least for the present, the use of the Cooper system would give designs as economical as any other loading which could be evolved. Railways the requirements of which for bridge loading were heavier than those of the Grand Trunk Pacific Railway might find it advantageous to adopt a system more nearly normal to somewhat heavier locomotives than those to which the Cooper loading will agree, but the writer thinks that the author is altogether wrong in proposing as a general standard a loading based on a normal to the few exceptionally heavy locomotives which he has chosen as the "heaviest existing locomotives".

HENRY S. JACOBY,* M. AM. SOC. C. E. (by letter).†—The author deserves much credit for the scientific manner in which he has investigated this subject,

* Prof., Bridge Eng. Emeritus, Ithaca, N. Y.

† Received by the Secretary, November 3d, 1922.

and the systematic form in which the paper is presented. The use of a composite standard loading and of the segments of the influence triangle for any truss member are especially noteworthy. The comparisons made between the results obtained for each of the seven heavy modern loadings that are selected for the composite standard and for the Cooper standard now in use, seem to answer most of the questions about their relationship, as far as static stresses are concerned.

The question may be raised, however, whether the proposed M-60 loading with its relatively lighter uniform train load will represent more closely the development of future actual live loads than the equivalent Cooper loading with its relatively heavier train load. This matter will require the composite judgment of a great number of railroad engineers in active practice.

If the officers of any railroad on which light motive power is used, are in doubt whether locomotives of any of the types considered by the author are likely to be adopted on their line in the future, and who, therefore, would hesitate to accept a standard like M-40 or M-50, an independent investigation can readily be made to decide the question. The time required for such an investigation would be short in comparison with that devoted to this subject by the author. Only the heaviest locomotives of each class now in use on the given railroad need to be considered. The spans can be limited to those which include, say, 90% of the bridges now in use. A study of the results for these short spans will soon indicate whether greater or less differences among themselves in equivalent uniform loads are caused by those locomotives for any given section or truss member than by the seven locomotives selected by the author. After selecting the equivalent uniform loads from which a special composite standard for that railroad may be derived, they can be compared with those given by the author to see whether they differ materially from those obtained by scaling down the corresponding values due to the M-60 loading. It may also be observed whether the differences are larger for the web members or the chord members. For plate-girder spans, the moments and shears are due to the locomotives alone, except for the small number having the largest spans.

In making a choice of one of the three loadings proposed by the author, it is well to remember that locomotive wheel loads were introduced in the United States nearly fifty years ago, and that numerous discussions since that time have failed to displace them. It is illuminating to re-read the discussion* held at the Annual Convention of the Society on June 27th, 1899. This is especially true with respect to forecasts made at that time regarding the increase of locomotive loads. Although a series of uniform loads determined by a formula may be more scientific, there are evident advantages in a series of wheel loads, which commend it to railroad officers outside the engineering department. With the aid of tables and diagrams, the computation of stresses is practically as simple in one case as in the other.

The fact that the American Railway Engineering Association concluded to retain the Cooper series of loading in its 1920 Specifications, after its Committee

* *Transactions*, Am. Soc. C. E., Vol. XLII (1899), p. 189.

had carefully re-investigated the subject, makes it necessary to present exceptionally strong arguments to secure a change in the near future. The extensive records now in use on the rating of railroad bridges in terms of the Cooper series make it inadvisable to introduce a change involving so many short span bridges, unless advantages are secured, which exceed in value that of the labor required.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

TENTATIVE PLAN FOR THE CONSTRUCTION OF A 780-FOOT ROCK-FILL DAM, ON THE COLORADO RIVER, AT LEE FERRY, ARIZONA

Discussion*

By Messrs. L. F. Harza and I. Gutmann.

L. F. Harza,† M. Am. Soc. C. E. (by letter).‡—The author proposes to build a dam about twice as high as any yet constructed, and of a type which as yet has been applied to a height only one-half as great as other types. The method proposed has been applied only to very small and unimportant or temporary dams of that type, and contemplates the formation of a storage reservoir that would be as large, if not larger, than any in existence, with valuable lands and human habitations in the lower reaches of the river. Whether such a project should be undertaken with the present knowledge of such structures hardly deserves serious consideration. Man has never been able to advance safely in the science of engineering by such stupendous strides, and this work, if it is undertaken, calls for the maximum degree of safety which engineering knowledge can provide.

As a hypothetical problem, however, serving by its very size to intensify the study and discussion of this type of structure, it should prove valuable in bringing out all the experiences, theories, and opinions bearing on this type of dam, for subsequent application to smaller structures.

In 1914, the writer proposed such a plan, on a smaller scale, as one of several alternative plans, although not the favored one, for closing the main channel of the Columbia River near The Dalles, Ore., after having completed a by-pass channel and gates of sufficient size to pass and control the entire flood flow.§

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* Discussion of the paper by E. C. La Rue, M. Am. Soc. C. E., continued from October, 1922, *Proceedings*.

† Cons. Hydro-Elec. and Hydr. Engr., Chicago, Ill.

‡ Received by the Secretary, October 9th, 1922.

§ "The Columbia River Power Project," Technical Publishing Co., San Francisco, Calif.

In this instance, the available rock-fill material was partly to be piled for this purpose behind large rubble retaining walls and was assumed to cleave on a plane inclined on a slope of 1 on 1, after the blasting of the retaining walls, thus furnishing sufficient material (about 900 000 cu. yd.) above this slope to divert the river completely.

The writer knows of one instance where a blast on a smaller scale was used to close a narrow river gorge under a head of about 100 ft. Subsequent attempts, extending over about 7 years, to seal this rock-fill with fine material have not proved successful, unless it has been accomplished recently. Local settlements of the fill occur periodically, which settle and crack the blanket of fine material, starting channels of flow which quickly enlarge until a hopper-like cavity forms in the blanket, through which water escapes freely into the coarse rock.

The writer believes that the principles which should determine the design of the blanket to tighten such a rock-fill dam are:

(*a*).—The material must be graded from coarse to fine by such gradual transition and by such definite and controllable means, that each size of material will be continuous over the whole surface and will be too coarse to be carried away through the pores of the next larger size.

(*b*).—That each layer must be of sufficient thickness to preclude the possibility of local settlements of the supporting rock causing fault slips in this blanket sufficient to bring the fine material in contact with material coarse enough to permit the fine material to be carried away by percolating water, and thus destroy the blanket locally.

(*c*).—Or, preferably, that the earth blanket, in addition to Requirement (*a*), should also be of the full thickness of an earth dam if standing alone and unsupported by the rock-fill, in order that the velocity of the seepage may be comparable to that in earth dams.

Obviously, Requirements (*a*) and (*b*) are difficult or impracticable of accomplishment when material is deposited under water on an irregular surface, as would be the case if the rock-fill was formed by a large blast from the adjacent walls. It might be argued that the natural process of percolation would eventually segregate the materials as demanded by Requirement (*a*). This, however, would require many years of repairing blow-outs, settlements, and cavities formed by the carrying out of material, before equilibrium would be established, if indeed it ever would be.

Requirement (*c*), if the up-stream slope of the rock-fill was 2:1, might result in a slope of about 7:1 or 8:1 for the final up-stream surface.

If an earth dam at full section was to be built up stream from the rock-fill, its foundation would require the same treatment, prior to the blast, that would be given to an earth dam constructed by the usual means. This would require under-flow cut-offs to bed-rock, the grouting of all fissures in the bottom and side-walls to be covered by the fill, and a liberal number of concrete cut-off walls in the bottom and sides of the gorge to prevent seepage along the contact between the earth and the rock, which otherwise might cause channels that eventually would threaten the safety of the structure.

The writer would like to cite certain observations bearing on the principles of the proposed type of dam. In British Columbia, there is a narrow canyon, through which a river flows with a flood of about 50 000 sec-ft. and with a fall of about 50 ft. per mile. Just above a narrow section, flanked with steep mountains about 8 000 ft. high, the river becomes suddenly sluggish and meanders through an alluvial plain that is about ½ mile wide and 30 miles long and as flat and marshy as any point along the Mississippi. The mountains rise abruptly on each side of this marshy plain, forming a section of valley like a "V," with a straight horizontal line half way up. This condition strongly suggests a natural dam formed by faulting or by a landslide at the transition from the marshy valley to the roaring canyon. Borings have proved it to be of landslide origin. Here is a natural rock-fill dam acting as its own spillway, which has been successfully silted by natural process. The down-stream slope, however, is about 100 : 1, and the silt blanket has filled the reservoir.

The writer studied and reported on another such instance in 1915, that of the Cascade Rapids in the Columbia River, which was reported in *Bulletin No. 5* of the State Engineer of Oregon.

The writer refers to this report because it conveys a lesson in conflict with opinions expressed in some of the discussions. The statement has been made that it would be difficult to reach the center of the fill with rock from the two walls. Undoubtedly, this would be the case if the rock was blasted to its resting place. If, however, it is merely dislodged along a cleavage plane so steep that the whole mass would tend to slide, the writer is not sure but that the center of the dam would be the highest.

The rock slide of the Cascade Rapids from an elevation of 3 420 ft. appears to have buried a river 1 mile away and diverted it to a new channel about 3 miles away, of which the detritus still forms the northern bank. Perhaps this is the result of the inertia of the slide and of a subsequent movement on a slippery bed. The writer also remembers having observed small avalanches with the outer nose of the detritus piled higher than that part closer to the mountain, or, at least, it so appeared without an instrument. So many plans for dams like that of the author, but on a smaller scale, have been proposed that it seems to be the natural impulse of almost every engineer, when he sees a narrow, deep canyon, to want to build a dam by the rock-slide method.

I. Gutmann,* Assoc. M. Am. Soc. C. E. (by letter).†—It has been suggested‡ by H. B. Muckleston, M. Am. Soc. C. E., that there is an analogy between the rock-fill dam, proposed by Mr. La Rue, and a natural landslip, which, in 1893, dammed the Birahi-Ganga, in India, and formed Gonha Lake. It may seem strange to compare the dam, which is proposed to be built by blasting rock from solid canyon walls, to a pile of rock formed by a natural landslip. The analogy, however, appears most appropriate and highly impressive after one learns, from the references pointed out by Mr. Muckleston, the following details of paramount importance:

* Brooklyn, N. Y.

† Received by the Secretary, October 31st, 1922.

‡ *Proceedings*, Am. Soc. C. E., September, 1922, p. 1607.

1.—That the Birahi-Ganga landslip consisted of enormous masses of limestone and Dolomite rocks, mixed with detritus and covered with a "thick layer of white impalpable powder."

2.—That the rocks sheared off from a steep hill and dropped from a height of 4 000 ft. above the bed of the stream.

3.—That the 900-ft. dam thus formed stood for about a year until it was overtopped.*

There seems to be sufficient mechanical similarity between slides of this type and the new method of dam construction suggested by Mr. La Rue, to justify further reports and studies of dams formed by natural landslips.

The writer can cite a similar occurrence, on a much smaller scale, which took place on the Jordan River, in Palestine, on December 8th, 1267. According to an Arab chronicle,† a hill on the west bank, near Damiah, fell into the river and kept it completely dammed for sixteen hours. The Jordan was in full flood at the time. From a direct knowledge of the river, the writer would think that the river may have carried from 2 000 to 3 000 sec-ft. The natural dam must have been composed of alluvial and diluvial earths.

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* *Journal*, Soc. of Arts, March 27th, 1896.

† "From the Garden of Eden to the Crossing of the Jordan", by Sir William Willcocks, Lond., 1920.

MEMOIRS OF DECEASED MEMBERS

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

SOLOMON LE FEVRE DEYO, M. Am. Soc. C. E.*

DIED AUGUST 19TH, 1922.

Solomon Le Fevre Deyo, the son of Jonathan Nathaniel and Maria Le Fevre Deyo, was born in Gardner, N. Y., on December 17th, 1850. He entered Union College at Schenectady, N. Y., and was graduated in the Class of 1870.

In 1870-71, Mr. Deyo was Instrumentman on the survey of the Town of Morrisania, N. Y., under the supervision of Gen. George S. Greene. In 1871, he entered the employ of the New York, New Haven and Hartford Railroad Company on the location of the Harlem River Branch, from Harlem River to New Rochelle, N. Y., and, later, was Resident Engineer on the construction of that road. In 1873, he entered the employ of the New York and Harlem Railroad Company, as Resident Engineer on the Fourth Avenue Improvement in New York City. In this position, he had charge of the section from Forty-seventh Street to Seventy-ninth Street, which work included the elimination of grade crossings and the construction of four tracks. He continued on this work until its completion in 1876.

From 1876 to 1881, Mr. Deyo was Superintendent of the American Metaline Company, New York City; from 1881 to 1883, Division Engineer on surveys with the South Pennsylvania Railroad Company; and from 1883 to 1885, Construction Engineer with the same Company. During 1886, he served as Principal Assistant Engineer on the Buffalo and Geneva Railroad, and, later, as Assistant Engineer with the Lehigh Valley Railroad Company.

In 1887, he was engaged in railroad reconnaissance in Northern Alabama for the Pioneer Mining and Manufacturing Company, and, later, in the same year, he was employed by the New York, New Haven and Hartford Railroad Company, as Assistant Engineer in charge of general work. He continued in this capacity until 1890, when he was appointed Assistant Engineer in charge of the Western District of the same road, resigning in March, 1900.

During the latter part of his service with the New York, New Haven, and Hartford Railroad Company, Mr. Deyo had supervision more particularly over the construction of additional tracks on the Harlem River Branch and the construction of the terminal yard at Oak Point, East River, including bulkhead, bridges, and approaches for the purpose of transfering cars to and from the boats.

In March, 1900, Mr. Deyo was appointed Chief Engineer of the Rapid Transit Subway Construction Company, New York City, which was organized by Messrs. August Belmont and John B. McDonald (after the latter had been awarded the contract) for the construction of the first underground rapid transit railroad in New York City. As is well known, the problems and dif-

* Memoir prepared by F. S. Curtis, Past-President, Am. Soc. C. E.

ficulties which attended this pioneer line were many, and Mr. Deyo, who personally supervised the writing of the numerous specifications and agreements for the sub-contracts for the several sections of the work, by his tact, ability, and foresight, kept the work up to schedule and frequently acted as harmonizer between the Rapid Transit Commission, with its demands for progress, and the sub-contractors who were doing the work. So well did the organization function under his direction that the great work was opened to public use on October 27th, 1904, just four years and seven months after the first official spadeful was turned. On January 10th, 1905, a banquet was tendered Mr. Deyo by his employees and co-workers, at which approximately seventy, including guests, were present, and a large silver punch bowl was presented to him.

Mr. Deyo also held the position of Chief Engineer of the Subway Division of the Interborough Rapid Transit Company (the operating company) until July 1st, 1905. On the organization of the Interborough-Metropolitan Company in 1905, Mr. Deyo was appointed as Chief Engineer and held this position until 1918, when he retired from active work.

He was married on June 24th, 1882, to Harriet Goodrich Brandon, who, with a daughter, Mrs. Royce R. Spring, survives him.

Mr. Deyo was of a quiet, reserved disposition, always approachable, having the confidence of all with whom he came in contact, not only those who worked for him, but also those for whom he worked. His fair treatment of all with whom he became acquainted was reflected in the number of his friends. His progress in life, in connection with his professional ability, was because of his kind and genial manner to everybody with whom he dealt.

He was a member of the Engineers' Club of New York City, which he had joined in 1893, continuing his membership during the remainder of his life. He had also been a member of the Holland Society of New York City since December 29th, 1892.

Mr. Deyo was elected a Member of the American Society of Civil Engineers on June 6th, 1888, and served as a Director of the Society from 1888 to 1900, and as Vice-President in 1904 and 1905.

CLEMENT ALEXANDER FINLEY FLAGLER, M. Am. Soc. C. E.*

Died May 7th, 1922.

Clement Alexander Finley Flagler was born at Augusta, Ga., on August 17th, 1867. He was the son of the late Brig.-Gen. D. W. Flagler, Chief of Ordnance, U. S. Army, and his mother was the daughter of Gen. Clement A. Finley, Medical Corps, U. S. Army.

The traditions of his family and his inherited soldierly qualities led naturally to his choice of the Army as a profession, and after his graduation from

* Memoir prepared by Chester Harding, Brig.-Gen., U. S. A. (*Retired*), M. Am. Soc. C. E.

Griswold College, Iowa, Mr. Flagler entered the United States Military Academy on June 14th, 1885. He responded fully to the rigorous training of that institution and, from the first, became a prominent and popular figure in his class by reason of his exceptional mental ability, combined with the rare charm of his personality. Possessed of a remarkably fine physique, he was a leader not only in his studies, but in the military drills and athletic exercises, prescribed and voluntary, that formed an essential part of the West Point training. The horizon of the West Point cadet has broadened since his day. Then, except for the ten weeks' furlough at the end of the second year, one never saw beyond the rugged skyline of the surrounding hills from the day of his admission to the Academy to the day of his graduation, four years later. Whatever time was left for amusement and recreation from the crowded hours of study and duty was utilized, if at all, in such diversions as the limited facilities of the cadets could command. Cadet Flagler's energy, keen sense of humor, and originality of resource made him the leading spirit in these enterprises, and contributed to the great popularity he enjoyed among his fellows. The warm and intimate friendships which he formed at West Point continued throughout his life. He was graduated with high honors on June 12th, 1889, and, on the same date, was assigned to the Corps of Engineers, U. S. Army.

His subsequent career was exceptionally varied and distinguished. After the completion of the three years' course of technical study at the Engineer School of Application at Willets Point, N. Y., to which the Engineer officers of the Army were assigned immediately after their graduation from West Point, Lieut. Flagler was stationed at San Francisco, Calif., as Assistant to the late Col. George H. Mendell, U. S. A., M. Am. Soc. C. E. for two years (1892-94), after which he was returned to the Military Academy as Instructor in Civil and Military Engineering. Thence, he was sent to Fort Monroe, Va., for a year's duty, and in 1896 to Portland, Ore., as Assistant in the Engineer District, with headquarters at that place. On the outbreak of the Spanish War, Capt. Flagler was promoted to the rank of Major and Chief Engineer of Volunteers, and served on the staff of Maj.-Gen. J. H. Wilson. He was in Porto Rico as Picket Officer and Assistant Engineer Officer, 1st Division, 1st Corps.

After the Spanish War, he was placed in charge of the Montgomery, Ala., Engineer District, for two years, and then was designated as Engineer Officer of the Department of Porto Rico and the Department of the East. He was in charge of the Wilmington, Del., Engineer District from 1904 to 1908, and of the Nashville and Chattanooga, Tenn., and Mobile, Ala., Districts for various periods from July, 1910, to July, 1913. While in the Wilmington District, he was a member of the Chesapeake and Delaware Canal Commission.

For the year ending May 7th, 1914, Col. Flagler was a Student Officer at the Army War College, Washington, D. C. During the disturbances in Mexico later in 1914, he served as Chief Engineer on the staff of the late Gen. Funston at Vera Cruz, and on his return from Mexico, he was detailed as Instructor at the Army War College until June 30th, 1915.

At the time of the entrance of the United States into the World War, Col. Flagler was in charge of the Washington, D. C., Engineer District, including the water supply of the City of Washington, the Key Bridge across the Potomac, and the development of the Anacostia Flats. In August, 1917, however, he was sent to Fort Leavenworth, Kans., in command of the 7th Regiment of Engineers and the Engineer Officers' Training Camp. On December 17th, 1917, he was commissioned Brigadier General, National Army, and was placed in command of the 5th Field Artillery Brigade, which he trained at Leon Springs and Waco, Tex., and which he took to France in May, 1918. Gen. Flagler commanded the Brigade at the front, in the St. Die, St. Mihiel, and Woevre Sectors. On October 17th, 1918, he was promoted to the rank of Major General and served as Chief of Artillery, 3d Army Corps, in the Argonne-Meuse drive, from October 15th to November 20th, 1918. After the Armistice, he commanded the 42d (Rainbow) Division in the march to the Rhine, from November 21st to December 14th, 1918, when it became part of the Army of Occupation, with Gen. Flagler as Military Governor of Kreiss of Ahrweiler, which command he held until his return to the United States in March, 1919. On April 6th, 1919, he was relieved of the command of the 42d Division, at Camp Bowie, Texas, and until April 6th, 1920, was in command of the Camp and Engineer School, at Camp Humphreys, Va. His next duty was in Honolulu, Hawaii, as Department Engineer, Hawaiian Department, Commanding Officer of the 3d Engineers, and in charge of the Hawaiian Engineer District. From May 1st, 1921, until his death on May 7th, 1922, Gen. Flagler was at Baltimore, Md., as Division Engineer of the Eastern Division of Fortification and River and Harbor work under the Chief of Engineers, U. S. Army.

This record, derived from official sources, of active participation in the service of the Government, during periods of peace and war, for the thirty-three years between his graduation from the Military Academy and his death, emphasizes the confidence placed in Gen. Flagler by the authorities of the War Department. He was assigned to positions of high responsibility and authority for which his tried abilities had shown him to be qualified. He was by selection one of those to whom especial training was given for high command in time of war, and during the two wars that occurred within the scope of his career, he held positions of great responsibility with the forces at the front. His energy, courage, and devotion to duty were inspiring to all those within his influence. Not only in the stress of battle, or in the performance of public duty in time of peace, but also in his intercourse with his fellow men, Gen. Flagler lived up to the highest ideals of honor and duty. The sense of devotion to duty, regardless of personal convenience or consequence, was never more highly developed than in him, and it constituted one of his most pronounced characteristics. He was a noble example of the high type of man who succeeds because he holds himself true to his honor, his duty, and his country.

Gen. Flagler was elected a Member of the American Society of Civil Engineers on March 13th, 1917.

TORAGORO KONDO, M. Am. Soc. C. E.*

Died July 17th, 1922.

Toragoro Kondo was born at Iino, a small village in the Niigata Prefecture, Japan, on June 1st, 1865. His early education was acquired in the public schools of his native Province, where his aptitude for study was generally recognized. It was this ability that caused him to be chosen by the Government, to be sent to Tokyo, in order to complete his studies—no small honor to a country schoolboy. After two years of keen competition in the Yobimon, or Preparatory School, Mr. Kondo succeeded in entering the Imperial University at Tokyo, from the College of Engineering of which he was graduated with honor in 1887.

Immediately after his graduation, Mr. Kondo proceeded with his classmate, Mr. Kobayashi, to the United States to study the practice of engineering in the office of the writer at Kansas City, Mo., and he was also in the employ of other Western engineers. During that time, he obtained much valuable experience in the design and construction of railway and highway bridges, water-works, sewerage, and pumping engines.

Like most Japanese engineers, Mr. Kondo was an apt pupil and a keen observer; consequently, during his two-year sojourn in the United States, he learned far more than most recent American graduates of his age would have learned in twice that time. Not only was he of an exceedingly high order of intelligence, but he also possessed a personality that made him popular with everybody with whom he was associated. He was always kind, considerate, just, and honorable; and it was this combination of qualities, as much, perhaps, as his fine technical ability, that enabled him to attain the eminent and influential position he occupied in the Engineering Profession of Japan.

As Chief Engineer of the Home Department for a quarter of a century, he was charged with the approval of all the important engineering works undertaken in Japan, with the sole exception of those relating to the railroads.

In his earlier practice, he planned and superintended river improvements of importance; and, in 1896, the Ministry of Education conferred on him the honorary degree of Kogaku-Hakushi, which corresponds both to the French degree of Docteur ès Sciences Appliquées and to the American degree of Doctor of Engineering. There is no distinction greater than this in the Japanese Empire; for, like membership in the Académie des Sciences of France, it stamps a man as eminent in science, and, in addition, it indicates that he is a successful technician. The selectness of this degree is most jealously safeguarded by the Government, and it is never bestowed for any other reason than real worth. In order to take this degree, Dr. Kondo presented an elaborate thesis on Hydraulics, in which field he had been studying for nearly a decade.

He was for years a member of the Earthquake Investigation Committee and also of the Harbor Commission. In every large exposition held in Tokyo since 1907, he had served as one of the Jurors. In 1915, Dr. Kondo accepted

* Memoir prepared by J. A. L. Waddell, M. Am. Soc. C. E.

a chair in the Imperial University of Tokyo, and after that date, he divided his time between administrative and academic work.

A brother engineer, who, to-day, stands at the head of the Profession in Japan, I. Hiroi, M. Am. Soc. C. E., writes, as follows:

"Dr. Kondo, besides being an engineer of remarkable ability, was a man of the highest integrity. In the performance of his duties the most important one of which was the examination of plans submitted for approval by resident as well as prefectural engineers, and by individuals for permits from the Ministry, he was never influenced by either fear or favor. His professional life was one of unswerving rectitude and vigilant discipline. He had far more lucrative positions offered to him from time to time by various corporations and individuals; but he faithfully stuck to his post until the day of his death. His fine character and affable nature won for him many friends and made him both respected and liked by all those with whom he came in contact. To young engineers he was particularly friendly, and he helped many of them to rise in the profession."

Dr. Kondo was married in 1901 to Miss Koh Kato, the daughter of an eminent Japanese philosopher and statesman. He is survived by his wife, three sons, and a daughter.

Dr. Kondo was elected a Junior of the American Society of Civil Engineers on October 3d, 1888, and a Member on June 5th, 1901.

DAVID MERIWETHER, JR., M. Am. Soc. C. E.*

Died June 20th, 1922.

David Meriwether, Jr., was born at Louisville, Ky., on February 27th, 1879. He was graduated from the Rose Polytechnic Institute, in the Class of 1900.

Immediately after his graduation, Mr. Meriwether entered the service of the Pennsylvania Railroad Company, in the Engineering Department. In 1901, he secured a position in the Construction Department of the Southern Railway Company, in which position his attention was given to location and construction work. He remained with this Company until March, 1920, during which period he rose from the position of Instrumentman to Assistant to the Chief Engineer. In addition to directing construction work on many miles of second track, he designed many yard layouts and terminals and some of the most important concrete structures on the Southern Railway.

In March, 1920, Mr. Meriwether entered the service of the United States Railroad Administration as Regional Engineer in charge of the Allegheny Region. In this capacity, he was called on to solve some of the difficult problems resulting from Federal control of the railroads, a task for which he was eminently fitted by his experience and judicial temperament. He was engaged in this work at the time of his death on June 20th, 1922. He is survived by a widow and two sons.

Mr. Meriwether was a thorough and painstaking engineer. During the last twenty years of his life, he was closely associated with the writer, and his sterling integrity endeared him to all with whom he came in contact.

Mr. Meriwether was elected a Member of the American Society of Civil Engineers on November 9th, 1920.

* Memoir prepared by E. M. Durham, Jr., M. Am. Soc. C. E.

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